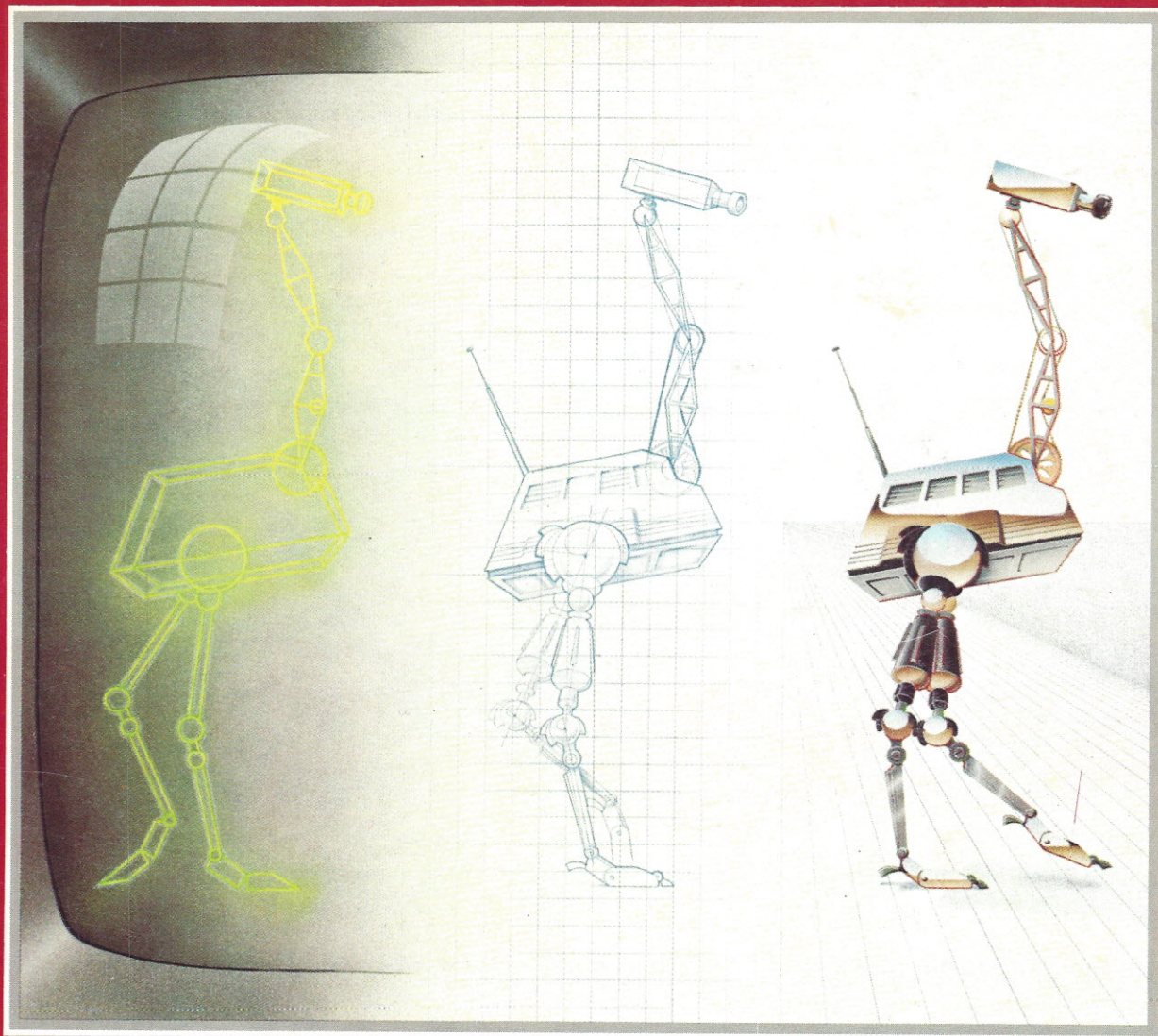


THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICSTM AGE



Introducing

SCORPION[®]

The Sophisticated Robot Kit for Unlimited Imaginations.

Enter the realm of SCORPION and let imagination be your guide. New from Rhino Robots, SCORPION provides extraordinary experimental capabilities at a surprisingly affordable price.

With a complete 6502 microprocessor on board, SCORPION is ideal for experiments in artificial intelligence, pattern recognition, hardware and software development, mobile robot theory and language.

Two KIM, SYM, AIM compatible expansion slots are provided. The system can be expanded to a 64K 8-bit computer, complete with keyboard and CRT. And SCORPION's 32 instruction command set allows for full interrogation and control via its RS-232C link. A 250-page manual contains detailed instructions for assembly and use.

Get acquainted with SCORPION today. Available now at computer stores and directly from Rhino Robots.

RS-232C interface and power cord enter a 12-pin connector to serve SCORPION's communication and power needs.

Controller can be easily expanded to run 2 additional motors (6 total) and provide 18 more I/O lines.

Cover not shown.

A bumper is provided on either side of SCORPION. Each bumper has 2 microswitches that are actuated upon collision. These 8 microswitches give the on-board computer detailed information about which section of SCORPION has encountered an obstruction, thus allowing intelligent recovery to take place.

The computer card provided with SCORPION is assembled and tested in the factory prior to shipment to ensure ease of assembly and trouble-free operation upon receipt.

Chassis made of .052" thick aluminum. Entire system is punched out on CNC punches to insure accuracy and quality.

Large 4.5" diameter molded wheels, driven by size 28 stepper motors, provide powerful traction for SCORPION. Each wheel can be run at any of 70 speeds in either direction.

A CdS cell at the focus of the optical scanner gives the system the ability to recognize up to 127 different brightnesses in its environment.

A polished, chrome-plated parabolic optical antenna provides the gain necessary to give the optical scanner its viable sensitivity.

2 small stepper motors allow movement of the optical scanner in horizontal and vertical modes. Instructions provide the capability of resetting and moving each axis and making a scan along each axis.

A 2" diameter speaker, whose frequency and duration of tone can be controlled from the host computer, is provided at the front. The speaker can be used to make robot noises, generate complicated sounds and play tunes.

2 lamps and 2 phototransistors, centered on the wheels and mounted on the PC board below SCORPION, provide the ability to detect floor brightness and allow the system to be programmed to read codes and follow complicated paths.

SCORPION's 2 eyes can be programmed to go on and off in any sequence to indicate intelligence, surprise or other expressions.

\$660.00 complete.
FOB Champaign, Illinois. Shipping included on pre-paid orders.
Manual only: \$20.00 prepaid.
Dealer inquiries welcome.

Coming soon from Rhino Robots: Voice, memory expansion and sonic distance detecting modules... plus other SCORPION accessories.

RHINO[®]

R O B O T S

RHINO ROBOTS, INC.

3402 N. Mattis Ave. P.O. Box 4010
Champaign, IL 61820
217/352-8485

Circle 18

**Now you can program HERO 1™
from your computer.**

It's a breakthrough by the crack robotics team at Virtual Devices! Meet MENOS I: the control system that brings HERO to life.

**MENOS I's software makes HERO
more fun to operate.**

It's as fast and easy as programming your PC. Because MENOS takes full advantage of a computer's keyboard, memory, and disks—to save you months of time and frustration.

MENOS even performs a diagnostic check every time you start operating. And when you write programs in our high-level

robotic language, MENOS prompts you and checks your syntax. You can edit quickly, then download programs to HERO.

A split window display of motor positions and sensor readings lets you monitor HERO's execution of your program. Or you can simulate the execution right on your computer screen. So you don't even need a robot to learn robotics!

**MENOS I's hardware gives HERO
a mind of its own.**

Besides a more powerful microprocessor and an RS-232 port, you get 34K of memory, with 3 operating systems in ROM—including an upgrade of HERO's own. Plus 4 expansion slots for more breakthroughs.

Our fee is very reasonable.

Especially now through March 31, 1984, when the introductory price is just \$395. With a 30-day money-back guarantee and a full year's warranty on parts and labor.

To find out more, call us or write us at P.O. Box 30440, Bethesda, MD 20814. Better still, order today. And get ready to perform a heroic feat of surgery.

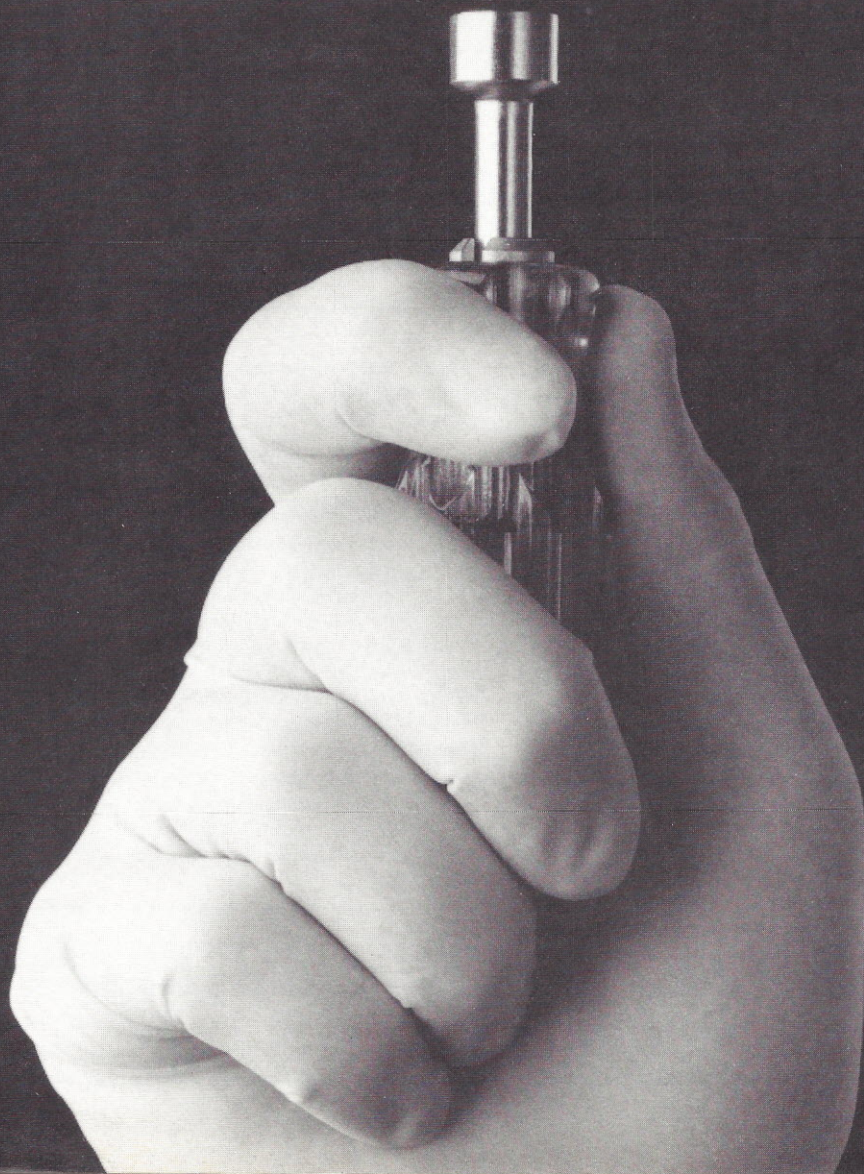
Call toll-free: 1-800-762-ROBO.

In Maryland, 301-986-1702.



Circle 23

WORLD'S FIRST BRAIN TRANSPLANT PERFORMED ON ROBOT.





PERSONAL ROBOTS

Peripherals and Software for Personal Robots

NEW

VOICE COMMAND SYSTEM FOR HERO

MICROMATION proudly presents a new peripheral for HEATHKIT'S® HERO-I robot which elevates the robot to a new level of sophistication. We call this peripheral a Voice Command System (or VCS) because it not only consists of a voice recognizer, but also an advanced level machine language program for the robot which actually allows you to program robot movements by voice. We call the voice recognizer VOREC and the voice driven program VOCOL (VOICE COMMAND Language). Highlights of these two important parts of the VCS are described below.

VOREC

VOREC is a powerful, microprocessor controlled, speech recognition board which mounts next to, and interfaces with, our HERO-I MEMCOM BOARD. The recognizer has the following principal features and specifications:

- Speaker-dependent recognizer with nearly instantaneous word recognition rates.
- Recognition accuracy about 98%.
- Vocabulary of up to 256 words (stored as 16 word groups with 16 words in each group for greater recognition accuracy).
- 16K of onboard static RAM of which 14K is battery backed to retain recognized word parameters during power down.
- RS232 port for receiving commands from, and reporting status and words recognized to, the host (HERO).
- Highly sensitive audio input circuitry requires only an external speaker for audio input rather than a microphone. (This allows robot to receive commands from up to 15 feet away.)
- Utilizes state-of-the-art high speed (HC) CMOS chips and the new CMOS 65C02 microprocessor for ultra low power consumption. Complete board consumes an incredibly low 45 ma while active and 1 ma when inactive.
- Speech recognition is accomplished by a software algorithm contained in a 2K EPROM. (Future product updates will require only replacement of this EPROM.)

VOCOL

This software is even more amazing than the voice recognition hardware. VOCOL is like a high level language for the robot (such as BASIC) which supports both deferred and immediate execution modes. The only difference is in BASIC you "write it," and in VOCOL you "speak it." The software is provided on an EPROM which plugs into a memory socket on our HERO-I MEMCOM BOARD. VOCOL has the following principal features:

- When first run, the robot talks to you through a voice training session in which you are asked to repeat words in his command vocabulary three (3) times.
- Following this training session, you can literally talk in a program of movements for later execution, or command immediate movement by voice.
- The robot prompts you for a command and when received, repeats it back to you for verification. If verified and if in immediate execution mode, the robot will execute the movement. If in deferred execution mode, the robot proceeds to write a machine language program in his memory for later execution. When your program of movements is complete, you signify this with a "STOP" command. A "GO" command will then cause the robot to execute the program it wrote in memory. After execution, the robot returns to the command mode.
- Complete instructions and installation manual.

The Voice Command System manual contains a complete description of how to use the VOREC board under program control from HERO. The 6808 Source Code for VOCOL is available on an APPLE® DOS 3.3 disk at additional cost. This source code is compatible with the SC-6800 CROSS ASSEMBLER.

VOCOL Source Code **\$55.00** (not sold separately)

TOTAL SYSTEM PRICE \$595.00

NEW

POET

This is an Artificial Intelligence program similar in concept to STORYTELLER, but more advanced. The program uses an advanced self-programming technique which allows the robot to speak self-generated, random three line Haiku poems on an endless list of subjects. After HERO speaks a poem and likes it enough, he will make a comment about it or do some meaningful body movement.

PRICE: TAPE (machine code) \$20.00

PRICE: DISK (source code) \$30.00

HERO MEMCOM BOARD

This product provides a means to develop programs for the robot using a personal computer, and expands the robot's memory with an additional 30K of RAM. This product includes:

- Two 8-bit bi-directional parallel ports with handshaking lines for superfast data transfers between the robot and a computer (connects directly to our APPLE-HERO COMMUNICATOR board), plus two 16-bit timers.
- An RS232 serial port for two-way communications between the robot and any computer having an RS232 serial port.
- Serial communications software in an onboard EPROM which allows uploading/downloading of programs via the serial port.
- Complete instruction manual and schematics.

PRICE \$295.00

APPLE-HERO COMMUNICATOR

This product provides the hardware and software necessary to implement two-way high speed parallel communication between an APPLE® computer and a HERO-I robot equipped with our HERO MEMCOM BOARD. It includes:

- A peripheral card for an APPLE that contains two 8-bit parallel ports with handshaking lines, and two 16-bit timers.
- Data transfer software for the APPLE board and for the HERO MEMCOM BOARD burned into two 2716 EPROMS. These programs provide ultra fast two-way communications.
- A disk containing heavily commented 6808 and 6502 source codes for the communications software. These source codes are compatible with the S-C MACRO ASSEMBLER and the S-C 6800 CROSS ASSEMBLER available for the APPLE from the S-C SOFTWARE CORPORATION.

PRICE \$159.00

Send check or money order to:

MICROMATION INC.

9104 Red Branch Rd.
Columbia, MD 21045



Add \$3.00 for shipping.

For information call:
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617-848-9306

ROBOTICS AGE—[ISSN 0197-1905] is published monthly by Robotics Age Inc., Strand Building, 174 Concord Street, Peterborough, NH 03458, phone (603) 924-7136. Address subscriptions, change of address, USPC Form 3579, and fulfillment questions to *Robotics Age* subscriptions, P.O. Box 358, Peterborough, NH 03458. Second class postage paid at Peterborough, NH and at additional mailing offices. **POSTMASTER:** Send address change to ROBOTICS AGE, 174 Concord St., Peterborough, NH 03458.

Subscriptions are \$24 for one year (12 issues), \$45 for two years (24 issues), \$63 for three years (36 issues) in the USA and its possessions. In Canada and Mexico, subscriptions are \$28 for one year, \$53 for two years, \$75 for three years. For other countries, subscriptions are \$32 for one year surface delivery. Air delivery to selected areas at additional charges, rates upon request. Single copy price is \$3 in the U.S., \$3.50 in Canada and Mexico, \$4 in Europe, and \$4.50 elsewhere. Foreign subscriptions and single copy sales should be remitted in United States funds drawn on a U.S. bank.

Address all editorial correspondence to the Editor at *Robotics Age*, Strand Building, 174 Concord Street, Peterborough, NH 03458. Opinions expressed by the authors of articles are not necessarily those of *Robotics Age*. To aid in preparation of acceptable articles, the *Robotics Age* Authors' Guide is available upon request if accompanied by a self-addressed 8½ by 11 inch envelope with first class postage for 3 ounces. Unacceptable manuscripts will be returned if accompanied by a self-addressed envelope with sufficient first class postage. Not responsible for lost manuscripts or photos.

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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS AGE™

FEBRUARY 1984

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About the cover: Powerful microprocessors and advanced software are providing engineers with new design and simulation tools. This month's cover illustration, by Jonathan Graves, portrays the modern design sequence from a workable computer model, through a complete prototype to the finished product.

BPA Membership (SMA Division) Applied for, August 1983

Simulation

The Need for Tools

Computer simulation of real-world activities has long been accepted as an economical way to test design concepts. Many computer-aided design systems allow engineers to construct and manipulate theoretical models as if they were real. Simulated airplanes are flown, automobiles are driven, and computer electronics are operated—all without the expense of constructing an actual product. Simulations provide engineers with the ability to test various design decisions in hours versus the potential days of altering mechanical models.

Simulation Requirements. There was a time, in the not-so-distant past, when a computer simulation meant a human operator developed a series of numbers and tables which described the operation to be simulated. These numbers were entered into a computer which, in turn, produced another set of numbers and tables. These results were then deciphered to determine if the operation had proceeded as expected.

Today's design engineer requires more: graphics, the ability to interact with the simulation, and real-time motion. The ability to define a robot system and then observe a graphical representation of that system in motion is much more useful than just receiving a list of numbers. The human brain makes use of as much information as is available, therefore, our tools should provide maximum

amounts of information in easily understandable packages.

Until recently, most complex simulations were performed using large, high-speed mainframe computers. The desktop computers lacked the speed, graphics ability, and memory capacity. However, the current breed of desktop computers are challenging the mainframes. Today, an engineer can place on a desk a computer system which once would have required a roomful of equipment.

With this new computational power comes the ability to provide new tools. An essentially required tool is a desktop computer system with graphics capabilities and a program which understands three-dimensional mechanics and kinematics. Such a system would allow engineers to simply describe an object's shape and mass distribution. Tables of material properties could be provided to describe the characteristics of materials used in the final product. Systems of linear differential equations operating on the tabular data produce predictions about system performance.

Such a system would provide real-time graphics and interaction between the design engineer and the model simulation. The engineer could place loads, move joints, and manipulate objects within the simulation environment to determine how the system reacts. The use of color would provide ways to plot various stress factors within a mechanical part.

The newest desktop microcomputers are probably

Continued on page 29

MARVIN MARK I

The Most Sophisticated Personal/Educational Robot Available

BRAINS

Single Board Computer/Motherboard
Processor- Motorola® M68000 16 bit microprocessor
System Memory- 128K bytes RAM expandable to 512K byte on board, expandable to 8M byte by S-100 board. ROM up to 16K bytes.
System I.O. 2-RS232 serial ports, one-parallel port. These are for communication with the outside world, internal communications between servos and computer are taken care of directly.
Expansion Bus- 8 slot S-100/IEEE-696 expansion bus.
Intelligent Servo Controller- Resident on the expansion bus is one S-100 card with 16-full 4 quadrant power MOSFET pulse width modulated servo controllers with axis feedback and auto refresh.

This Iowa Precision Robotics Ltd. Model 68-100 computer supports CP/M® 68K and Forth operating systems. It is also used in our Industrial Robot Controller where it meets exacting requirements.

BEAUTY

Anthropomorphic design sculptured body skin adds a finishing touch to the fully machined aluminum inner structure.

IOWA PRECISION ROBOTICS, LTD.

908- 10th Street, Milford, Iowa 51351 Phone (712) 338-2047

BRAWN

Two arms, each with:

Axis One: Shoulder is powered thru 135°. The motion you use while bowling.

Axis Two: Shoulder is powered thru 105°. The motion you use doing jumping jacks.

Axis Three: Upper arm is powered thru 135° of rotation. The motion you use while arm wrestling.

Axis Four: Elbow is powered thru 115°.

Axis Five: Wrist is powered thru 90°.

Axis Six: Gripper opens up to 2½ inches and closes down to zero.

All arm servos are powerful enough to enable 'MARVIN' handling a minimum five pounds load in each gripper. (A six pack of your favorite beverage weighs approx. 4½ lbs.)

In addition to the 12 arm axes, 'MARVIN' has:

Neck is powered thru 180° rotation.

Waist is powered from straight up to 50° forward. This enables him to reach the floor with his grippers.

Drive Wheels- Each drive wheel is an individual servo to enable directional control. His maximum rate of forward speed is 50 inches per second and he has enough power to climb a 10% incline.



International Personal Robot Congress

ALBUQUERQUE, NEW MEXICO April 13-15, 1984

ABOUT THE CONGRESS...

IPRC '84 will offer an opportunity for robot enthusiasts to display their creations and enter them in various *competitions*. There will also be *commercial exhibits* and *seminars* on personal robots, as well as *cultural events* portraying the history and mythology of personal robots.

The Congress will open with a major ceremony—an event complete with dignitaries, limelight, media, robots and fanfare. The Congress will close with an Awards Brunch recognizing the individual achievements of the Personal Robot Developers in their exhibitions and competitions.

PROGRAM

- SOFTWARE DESIGN CONSIDERATIONS
- HARDWARE DESIGN CONSIDERATIONS
- ROBOTS IN EDUCATION
- HUMAN SERVICES
- LEGAL ISSUES
- BUSINESS OPPORTUNITIES
- FUTURE OF PERSONAL ROBOTS

PERSONAL ROBOT DEVELOPERS: COMPETITIONS

The Personal Robot Developers (individuals, clubs, classes . . . whoever has a robot worth seeing) will exhibit their creations for a modest fee at the Robot Shops. Their operators can maintain, repair and modify their systems in these shops in view and within speaking distance of interested exhibit attendees. The PRDs will engage in a series of competitions. Awards will be given in the areas of "most useful", "most entertaining" and "open". The categories of competition will be junior/senior high school, college, and general. Competition will culminate with the "Golden Droid" awards to be presented at the Sunday Brunch.

CONGRESS REGISTRATION

Each registration includes admission to:

- opening ceremony
- technical sessions
- commercial exhibits
- Robot Shops and competitions
- featured speeches
- Awards Brunch

Before Feb. 15: \$125.00* (U.S. Dollars)
After Feb. 15: \$145.00* (U.S. Dollars)

WHO WILL ATTEND...

MANUFACTURERS are coming with the first generation of the commercial personal robots.

PERSONAL ROBOT DEVELOPERS are bringing their own robots from their private workshops and labs.

SUPPLIERS OF ROBOT GEAR are showing batteries, sensors, motors, wheels, tracks, gears and garments that are the material of robots.

EDUCATORS are coming to discuss what and how we can learn from robots.

SOFTWARE DEVELOPERS will show wares that give purpose and promise to robots.

LAWYERS are coming to explain, discuss and define the place of personal robots in the order of our society.

MEDICAL PERSONNEL are coming to find out how personal robots can assist the elderly and handicapped.

JOURNALISTS are coming to record and report the beginning of the era of personal robots.

MARKETING EXPERTS are coming to tell us how to move personal robots into all of our daily lives.

CAPTAINS OF INDUSTRY AND FINANCE are coming to illuminate the special opportunities and problems of personal robots in business.

WEAVERS OF DREAMS are coming. . . the writers and romantics who point the way.

STUDENTS, HOBBYISTS, ROBOT ENTHUSIASTS FROM AROUND THE WORLD are coming to exchange information, to observe all the wonders and to be part of the beginning.

IPRC '84 REGISTRATION FORM

Name: _____

Passport #: _____
(if not U.S. Resident)

Company Name: _____
(if applicable)

Address: _____
(or P.O. Box No.)

City: _____ State: _____

Country: _____ Zip: _____

Area Code: _____ Phone: _____

No. of Registrations: _____

Amount Enclosed: _____ *

For correspondence and remittance, mail to:
International Personal Robot Congress
1547 South Owens Street, #46
Lakewood, Colorado 80226 U.S.A.
303/278-0662

Calendar

FEBRUARY

February-May. The Robot Exhibit: History, Fantasy, and Reality. American Craft Museum II at International Paper Plaza, 77 West 45th Street, New York, NY. Contact: Susan Harkavy, American Craft Museum II at International Paper Plaza, 77 West 45th Street, New York, NY 10036, telephone (212) 397-0605.

The Robot Exhibit places the robot into social and historical context, tracing its nearly 5000-year development by displaying approximately 200 objects and major illustrations. Topics to be covered include: The History of Robots and Automatons; Interpretations of Robots; and Working Robots. Working robots, robot sculpture, toys, prints, photographs, slides, books, and video tapes will be lent by public and private collectors, artists, designers, inventors, and robot manufacturers.

MARCH

15-16 March. Technology Outlook. The Wisconsin Center, Madison, Wisconsin. Contact: University of Wisconsin—Extension, Department of Engineering and Applied Science, 432 North Lake Street, Madison, WI 53706, telephone (608) 262-3748.

This seminar is for industrial executives seeking an understanding of technology, and in particular, what is likely to occur in the next five years. The seminar will focus on four primary areas: telecommunications, automation, computer advances, and genetics.

Applications-Oriented Approach to Artificial Intelligence, Course #994OF. Orlando, Florida. Contact: George Washington University, Continuing Engineering Education, School of Engineering and Applied Science, Washington, DC 20052. (202) 676-6106, (800) 424-9773.

This course provides an understanding of the design, application, and implementation of an "intelligent" system based on artificial intelligence processing techniques that are directly applicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing an intelligent system based

on artificial intelligence processing techniques. The program is designed for project and design engineers, scientists, systems analysts, and technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence based systems.

19-21 March. IEEE 1984 International Conference on Acoustics, Speech, and Signal Processing. Sheraton Harbor Island Hotel, San Diego, CA 92131. Contact: Sam S. Vilione, Interstate Electronics, 707 East Vermont Avenue, Anaheim, CA 92805, telephone (714) 772-2811 X6327.

APRIL

Call for papers. The Workshop on Nonmonotonic Reasoning is sponsored by the American Association for Artificial Intelligence. The workshop aims to assemble theoreticians and practitioners from across the AI field who recognize a need for nonmonotonic reasoning. The objective is to identify those forms of plausible reasoning which arise in different areas of AI, to isolate common patterns, to entertain various accounts of these reasoning patterns, and to evaluate their suitability and limitations. For more information regarding manuscript submission, due by 1 April, contact: Ray Reiter, General Chairman, Department of Computer Science, University of British Columbia, Vancouver, BC V6T 1W5, CANADA.

Call for papers. The National Conference on Artificial Intelligence, AAAI-84, is the fourth national conference sponsored by the American Association for Artificial Intelligence. It will be held in Austin, TX on 6-10 August 1984. The purpose is to promote scientific research of the highest caliber in AI by bringing together researchers in the field and by providing a published record of the conference. Authors are invited to submit papers on: AI and Education, AI Architectures and Languages, Automated Reasoning, Cognitive Modeling, Expert Systems, Knowledge Representation, Learning, Methodology, Natural Language, Perception, Philosophical and Scientific Foundations, and Robotics. For more information regarding

manuscript submission, due by 2 April, contact: American Association for Artificial Intelligence, 445 Burgess Drive, Menlo Park, CA 94025, telephone (415) 328-3123.

Robot Olympics. California State College, San Bernardino, CA. Contact: Robot Olympics Committee, Computer Center, California State College, 5500 State College Parkway, San Bernardino, CA 92407.

The first Robot Olympics will be held on a weekend in April. Sponsored by various robot manufacturers, software developers, publishers, and dealers, the weekend will also sponsor introductory and application workshops. Competitions are designed for school grades kindergarten through 12.

23-26 April. Robotics and Remote Handling in Hostile Environments. Sheraton Hotel, Gatlinburg, TN. Contact: Norbert R. Grant at (615) 574-7123 or Howard W. Harvey at (615) 483-0228, or write to Technical Program Chairman, PO Box 326, Oak Ridge, TN 37830.

The meeting is sponsored by the American Nuclear Society's Remote Systems Technology Division (ANS/RSTD) and the Oak Ridge/Knoxville ANS Section. Session titles are: History of Manipulators and Robotics; Sensory Systems; Control Technology; Manipulator and Robot Applications; Remote Systems Applications in the Nuclear Industry—Fission; Remote System Applications in Other Hostile Environments; Technology Development and Remote Systems Technology Developments at ORNL.

Applications-Oriented Approach to Artificial Intelligence, Course #994DC. Washington, DC. Contact: George Washington University, Continuing Engineering Education, School of Engineering and Applied Science, Washington, DC 20052, telephone (202) 676-6106, or (800) 424-9773.

This course provides an understanding of the design, application, and implementation of an "intelligent" system based on artificial intelligence processing techniques that are directly applicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing an intelligent system based

Calendar

on artificial intelligence processing techniques. The program is designed for project and design engineers, scientists, systems analysts, and technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence-based systems.

MAY

7-11 May. 1984 Computer Aided Engineering and Manufacturing Seminars and Exhibition. North Carolina State University, McKimmon Center, Raleigh, NC 27605. Contact: Alice Strickland, NCSU, Division of Continuing Education, Box 5125, Raleigh, NC 27650, telephone (919) 737-2261.

JUNE

4-7 June. Robots 8. Cobo Hall, Detroit, MI. Contact: Jeff Burnstein, Robotics Institute of America, PO Box 1366, Dearborn, MI 48121. (313) 271-0778.

Robots 8 is the eighth annual national show sponsored by RIA.

19-21 June. 3rd Canadian CAD/CAM & Robotics Exposition and Conference. Toronto International Centre of Commerce, Toronto, CANADA. Contact: Hugh F. Macgregor & Associates, 662 Queen Street West, Toronto, Ontario M6J 1E5 CANADA, telephone (416) 363-2201.

This exposition is the major Canadian marketplace for advanced manufacturing systems. Conference topics include: Robotics Justification for Management, CAD/CAM, Robotics Education, Robotics Socio-Economic Considerations, Robotics Engineering, and Robotics Applications.

JULY

9-12 July. 1984 National Computer Conference. Las Vegas Convention Center, Las Vegas, NV. Contact: Ann-Marie Bartels, Las Vegas Convention Center, Las Vegas, NV, telephone (703) 558-3613.

Enhancing Creativity is the theme of the Twelfth annual NCC. The conference will focus on how the widespread availability of computing resources is altering the office, factory, and home.

23-27 July. SIGGRAPH '84. Minneapolis, MN. Contact: SIGGRAPH Conference Office, 111 East Wacker Drive, Chicago, IL 60601, telephone (312) 644-6610.

This year's SIGGRAPH Conference attendees will be treated to a vast array of technical and exhibit offerings. The program includes up to 30 one or two-day courses, panels on topical computer graphics issues, a larger number of exhibits, a design arts show, and the premier

of the first totally computer-generated Omnimax film.

NOVEMBER

27-29 November. Robots-West. Anaheim Convention Center, Anaheim, CA. Contact: Jeff Burnstein, Robot Institute of America, PO Box 1366, Dearborn, MI 48121, telephone (313) 271-0778.

Robots-West is RIA's first regional show. It will feature exhibits by leading robot manufacturers and component suppliers. Approximately 6,000 visitors are expected to attend the three-day exposition and conference.

TOTAL CONTROL:

**FORTH: FOR Z-80®, 8086, 68000, and IBM® PC
GRAPHICS • GAMES • COMMUNICATIONS • ROBOTICS
DATA ACQUISITION • PROCESS CONTROL**

• **FORTH** programs are instantly portable across the four most popular microprocessors.

• **FORTH** is interactive and conversational, but 20 times faster than BASIC.

• **FORTH** programs are highly structured, modular, easy to maintain.

• **FORTH** affords direct control over all interrupts, memory locations, and i/o ports.

• **FORTH** allows full access to DOS files and functions.

• **FORTH** application programs can be compiled into turnkey COM files and distributed with no license fee.

• **FORTH** Cross Compilers are available for ROM'ed or disk based applications on most microprocessors.

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Sensory Perceptions

TOURNAMENT OF ROBOTS. A fire-extinguishing robot took top honors at Advanced Computer Product's recent Tournament of Robots competition in Santa Ana, California. Chip, the robot, won an Apple IIe computer for designer Geoff Schulz in a contest which included commercially developed and home-built models.

The robot competition—part of a computer club swap meet—attracted a large crowd of electronics engineers, experimenters, and children who were fascinated by both the shiny, store-bought robots, and the one-of-a-kind home-built versions.

Entries from as far away as Silicon Valley were judged in a number of categories, including overall ability, design, dexterity, and maze-solving skill.

The tournament was conceived by Dave Freeman, President of Advanced Computer Products. Dave reasoned, "Household robots will be commonplace in the not-too-distant future. We wanted to demonstrate the latest developments in this fascinating field."

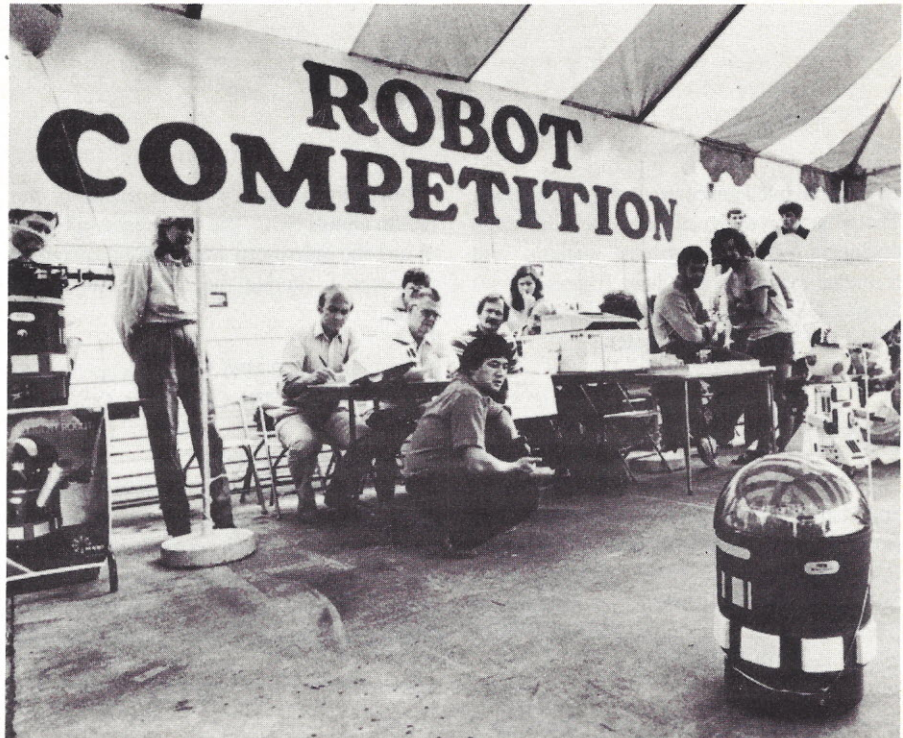
More competitions are planned for 1984.

ROBOT OLYMPICS. In recent years the personal computer has become commonplace in our society. The personal robot may possibly become just as popular. Schools have begun to introduce robotics as the logical and physical extension of computers. Since robots are fascinating to students of all ages, they motivate the study of computers and logic at various grade levels. The programmed functions of robots physically reinforce the student's exercises in computer programming and logical thinking.

In an effort to coordinate educators' efforts throughout the country, the California State College-San Bernardino has developed the Robot Olympics, a series of local, state, and national competitions aimed at increasing the amount of robot information available in schools from grade kindergarten through 12.

For more information about these competitions, contact: Robot Olympics, Computer Center, California State College-San Bernardino, 5500 State College Parkway, San Bernardino, CA 92407.

ROBOT CONGRESS. While on the subject of personal robots, don't miss the International Personal Robot Congress & Exposition 1984 schedules for 13-15 April in Albuquerque, New



Mexico. IPRC '84 offers an opportunity for robot enthusiasts to display their creations and enter them in various competitions. IPRC '84 will also feature commercial exhibits and seminars on personal robots as well as cultural events portraying the history and mythology of personal robots.

The Personal Robot Developers (noncorporate individuals, experimenters, and students) will engage in a running series of competitions and performances in which their robots show what they can do. The competition will culminate in the Golden Droid Awards.

For more information, contact: Joseph H. Bosworth, Chairman, IPRC Steering Committee, 1547 South Owens St, #46, Lakewood, Colorado 80226, telephone (303) 278-0662.

MICROBOT ADDITIONS. Microbot, Inc. of Mountain View, California has expanded their line of TeachMover™ and MiniMover™ robots. An Accessory Expansion and Sensor Interface for the TeachMover provides EEPROM memory sufficient for storing 126 step programs. Five digital inputs can sense limit switches, photoelectric switches, optical interrupters, push-button controls, position sensing switches and proximity switches. Three outputs can control solenoids, lights, motors, counters, alarms and pneumatic grippers.

An Experimenter's Kit includes tools, components, and documentation for sensor-based experiments. Additional accessories include a Tutorial Software Package, End-Effector Attachment Flange, Pneumatic Gripper, and a software/hardware package for connecting the TeachMovers and MiniMovers to TRS-80 Model I and III/4 computers.

FORTH ROBOTS. The Proceedings of the 1983 Rochester Forth Applications Conference is currently available from The Institute of Applied Forth Research, Inc., 70 Elmwood Ave., Rochester, NY 14611. An entire section of the conference was dedicated to the use of Forth in industrial, experimental, and personal robot design. Titles of papers include: *The Industrial Robot*; *They, Robots*; *System Architecture of the Laboratory for Perceptual Robotics*; *Forth-Based Products for Robotic Applications*; *A Robotic Application for Contamination-Free Assembly*; *Control of a Cartesian Robot*; *Expert System for Diesel Locomotive Repair*; *Forth and Automation Research at the National Bureau of Standards*; *A Robot Language for Two Unique Applications*; and *Improvement of a Human/Robot Interface Through the Use of Forth*.

Forth enthusiasts should consider subscribing to *The Journal of Forth Application and*

Sensory Perceptions

Research published by the Institute of Applied Forth Research, Inc. Many of the articles in the first issue were concerned with the use of Forth in robot control and expert systems.

ROFAC. SMC Management Technology has developed a computer-based robot selection system. Dubbed ROFAC for Robot-Factor, the method consists of computer programs which select candidate robots from a large data base, calculates the cycle time for specified tasks, and calculates the return on investment. For more information contact: SMC in Bridgewater, NJ, telephone (201) 685-9000.

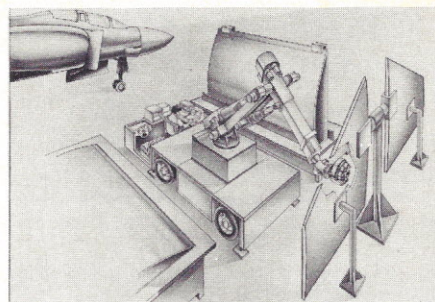
ROBOT TRAINING. Lennox Education Products provides several training programs specifically designed for the industrial robotics fields. Products and programs range from using simple pick-and-place robot arms to more advanced computer-controlled assembly robots. To find out more about the training programs, call Lennox at (214) 783-5463.

Riveting News. Southwest Research Institute of San Antonio, Texas is developing a mobile robot system capable of removing rivets from aircraft wings without damaging the wing. The Robotic Deriveter System (RDS) is scheduled for delivery in mid-1985 to the Naval Air Rework Facility at the North Island Naval Air Station in San Diego.

At present, removing wing rivets is a high-skill, labor-intensive operation. Precise drilling operations are required. Drill center location, drill orientation, and hole depth are all critical factors. After drilling, the rivet or fastener is removed by a properly sized punch driven by a pneumatic hammer.

The automated operation calls for the RDS to locate and center drill equipment with an accuracy of approximately 0.005 inch, and to remove rivets at a rate of one every 30 seconds.

The system will consist of a computer-controlled, electrically-driven robot using sensory feedback to help direct the actions of a set of tools. A solid-state, intelligent vision system



will enable the robot to perform three crucial tasks. It will identify the specific type of fastener to be removed, it will determine the precise fastener diameter, and it will calculate the adjustments required to relocate the end effector precisely in line with the rivet center.

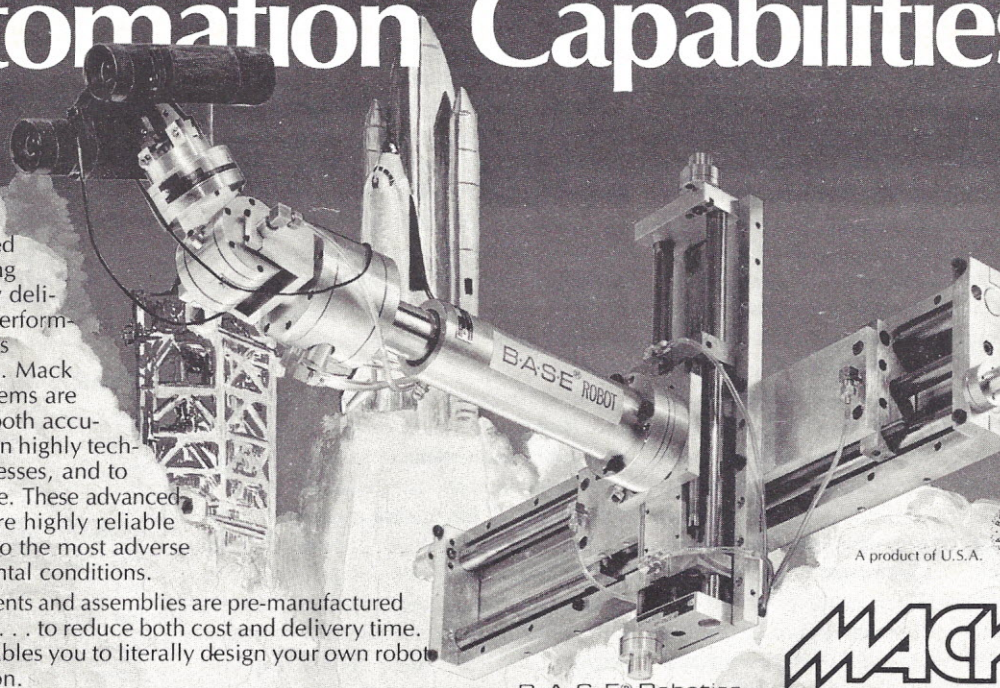
A key factor in system accuracy is the use of eddy current sensing technology. Eddy current inspection allows the RDS to detect the interface between a rivet and the skin covering the aircraft. It can also determine the type of metal from which the fastener is constructed. The eddy current sensing method provides the necessary accuracy for determining the exact center of the rivet or fastener.

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Educational Directions

University of Rhode Island Robotics Research Center

The University of Rhode Island's connection with robotics began in the College of Engineering, when students constructed the Mark I robot arm. Later efforts in the design and construction of robot arms and grippers culminated with the Mark IV, an accurate and reliable robot arm which was used in a number of important experiments. Having demonstrated that they could produce a robot as such, the researchers turned to the challenge of enabling robots to see and feel. This is the area that is the basis for the creation of a generation of industrial robots.

The present robot population is severely limited. They can only operate in workplaces which have been oriented especially for them. In the actual factory environment, parts are normally available on unordered worktables or bins. Under these circumstances, pre-orientation is at best an inconvenience, at worst a luxury that limits the robot's efficiency.

Consequently, the project at the center of the URI researcher's work has been the discovery and development of general methods by which robots with machine vision and other sensors can acquire, orient, and transport randomly presented workpieces—the so-called bin-picking problem. In 1975 the National Science Foundation (NSF) began its continuing support of the robotics research group for work on this subject. In 1980, seeking direct support from the ultimate beneficiaries of much of its research—private industrial corporations—the robotics group initiated an Industrial Participation Program in Robotics. This flexible cooperative program for technology transfer now comprises about 25 firms. URI researchers (a group now drawn from the faculty, graduate students and undergraduates of the departments of Electrical, Mechanical, and Industrial Engineering) consult with industry representatives, gathering information on their workplace problems which is then distilled into research projects that aim to provide generic solutions. In 1982, the NSF supplemented these industrial contributions with a four-year grant, as part of its efforts to foster fruitful industry/university cooperative research. URI is the only school to be given such a grant in robotics,

by virtue of which the Robotics Research Center was formally created.

The thrust of the Center's research is the creation of software and integrated systems, rather than a toolshed of ready-to-market devices. Some specialized hardware is fabricated in-house (gripper hands in particular), but off-the-shelf components are used whenever possible. Not only does this avoid reinventing the wheel, but it also smoothes the eventual transfer of technology from the laboratory to the factory floor.

The projects undertaken at the Robotics Research Center can be briefly summarized under several headings.

The first major project, bin-picking, was effectively completed using the URI Mark IV robot arm, video cameras, a raster graphics display system, a control computer, and software written by the staff. A number of subsequent projects have used this approach on workpiece types that are problematic because of their small size, delicacy, lack of good holdsites, poor visual characteristics, or other criteria.

Several projects have dealt with machine vision, translating neutral video images into meaningful instructions or inspection data.

Other projects are directed at the design of better types of mechanical sensors for force, proximity, and orientation. A variety of hands (end-effectors) have been designed and fabricated for special purposes: a rotating-belt hand for orientating cylindrical pieces; an air-servo operated hand; two kinds of suction-gripper hands for acquiring smooth pieces; and the much-used parallel-jaw gripper whose simple geometry allows it to reliably grasp a wide variety of objects.

Submitted by:
Robert B. Kelley
Director, Robotics Research Center
University of Rhode Island
Kingston, RI 02881

Research for the next generation of robots will entail the integration of senses, and the development of "smart robots" that have limited machine intelligence capable of selected components of the rational decision making of a human operator.

Patents for the bin-picking system and one of the suction grippers are among those secured so far by URI's robotics researchers.

In addition to the myriad of purely technical problems to be studied and solved, the advent of robotics to the world of industry brings with it economic considerations characteristic to high-technology operations. Studies have been made at URI of discounted cash-flow methods for robot systems and on-machine labor as the fourth cost of manufacturing.

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GRASP

From Computer Aided Robot Design to Off-line Programming

Stephen Derby
Assistant Professor

Mechanical Engineering, Aeronautical Engineering
and Mechanics Department
Rensselaer Polytechnic Institute
Troy, New York 12181

Determining whether a particular robot arm can accomplish a desired task can be time-consuming. Typically, you are forced to assemble a model of the planned workplace and physically test the selected robot and supporting equipment. This method often leads to multiple trials of custom-designed grippers and possibly several different arm modifications. In addition to being costly, this method precludes the ability to easily reprogram the arm, a main goal of flexible manufacturing systems.

The GRASP program, developed at Rensselaer Polytechnic Institute Department of Mechanical Engineering, provides a method for designing new robots, modifying existing ones, or just trying new application configurations. You can describe simulated robot workplaces which are drawn on a vector display screen. As the robot moves about the simulated workplace, the graphics display is updated. Since GRASP is interactive, it eliminates the need to write robot simulations directly in a high-level computer language.

Using GRASP. Before using GRASP, you must decide on the type of arm, hand, and workspace to be modeled. GRASP asks for all pertinent data and creates the needed data files, but considering the multitude of possibilities of robot and workspace designs, you should first sketch both the robot's geometry and the workspace's overall scale.

Arm Model. Properly defining a robot arm's spatial geometry is important in order to obtain useful results. Since many industrial robots are extensions of planar mechanism designs, the simulation may be simplified

by considering some arm links to be planar objects. However, these simplifications may require that the variables describing the arm's geometry be redefined for each arm. A general systematic approach, as described by Uicker, et al., is more desirable for the sake of programming.

GRASP allows you to model arm parameters such as arm dimensions, weights and/or densities, material properties, joint limits, and actuator performance curves.

Hand Model. Since no general-purpose gripper is suitable for all industrial tasks, the gripper is often a major redesign area. GRASP allows you to choose from a welder/sprayer, a vacuum cup, a palletizer, and a two-finger gripper. Specialized grippers may be simulated by describing their kinematic properties.

Workspace Model. From the manufacturer's viewpoint, the workspace and all that

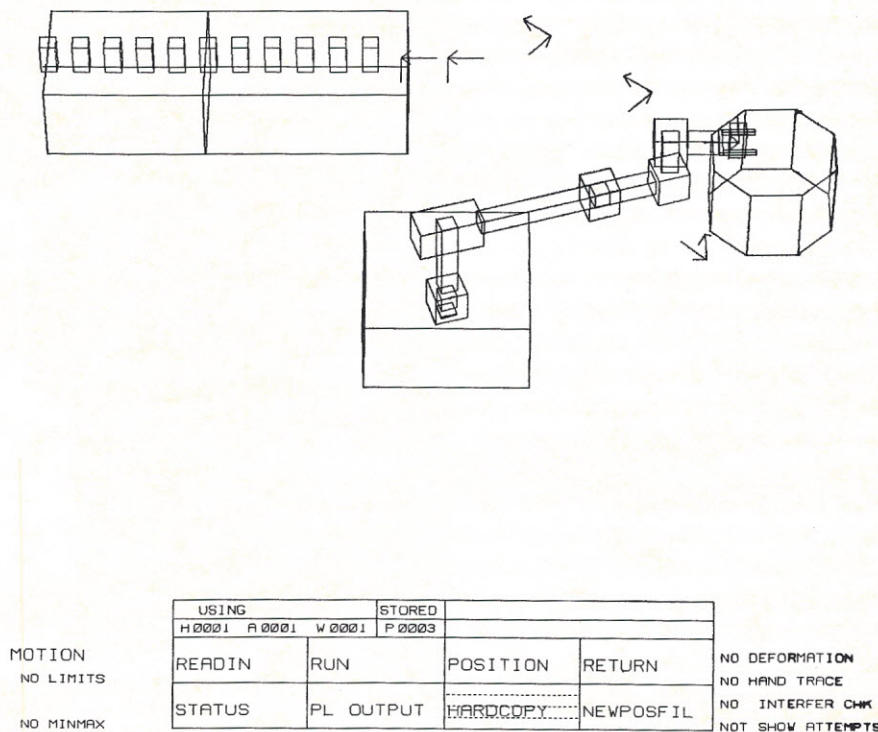


Figure 1. A generic, six-axis robot arm simulation showing the robot's relationship within the workplace. The vector-arrow pairs define the arm's path from the worktable to the conveyor where an object is grasped and then transferred to the worktable.

it encompasses is often fixed by past and present operating methods. Since workspace modeling is very important to a potential robot user, it must be described in sufficient detail to satisfy both the designer and the potential manufacturer considering the robot workplace.

Motion Characteristics. GRASP allows you to control the robot's motion by using a built-in set of motion primitives. Straight line, joint interpolation, acceleration, and deceleration commands are all available. Objects can be grasped and transferred, and conveyors can be moved. All these motions are displayed on the graphics screen.

Figure 1 shows the GRASP model of a six-jointed robot. The path is described by the graphical definition of the vector pairs. Animation is not performed in real time since the program currently runs on a time-shared computer system. The resulting motion of the first actuator joint as the robot moves from the worktable to the conveyor is shown in figure 2. The total time of 4.88 seconds is computed as a sequence time cycle.

Off-line Programming. In addition to designing robots and robot workstations, GRASP has been used for the off-line programming of two industrial robots. A Cincinnati Milacron T3 robot and a Puma 600 robot have both been programmed from the results of a GRASP simulation. This simulation method eliminates the need to tie up the robots while designing new sequences. Only fine tuning of detailed work needs to be added to the actual design.

Figure 3 shows the Cincinnati T3 model and an example workplace. The data generated from the GRASP simulation is translated into a language specifically designed for controlling the T3. Figure 4 shows the Puma model in a working environment. Once the GRASP simulation is designed and tested, the results are translated into a VAL program.

Conclusion. Programs such as GRASP will be of increasing value to robot designers and application programmers. The expense of a single robot can easily justify the costs of computer-aided design and time saved by off-line programming. □

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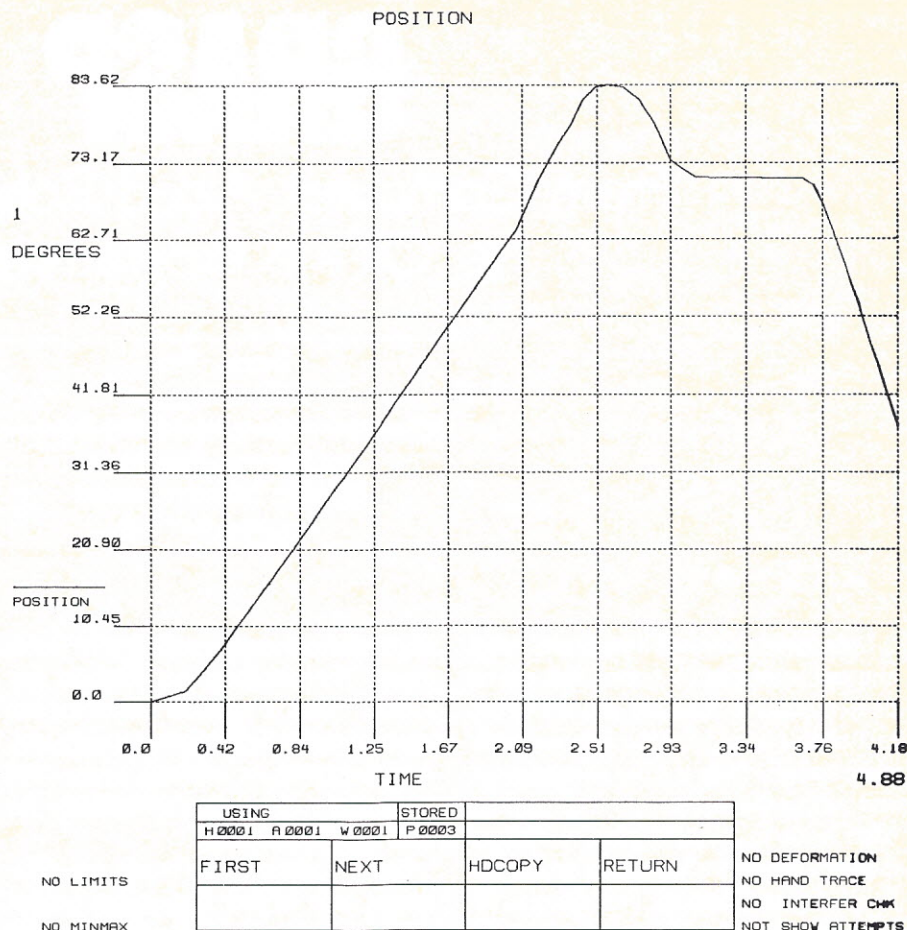


Figure 2. This graph shows how the six-axis robot's first joint angle moves as the robot moves from the work table to the conveyor.

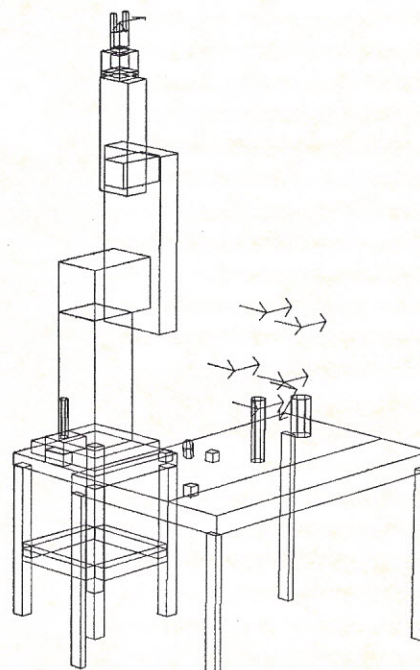
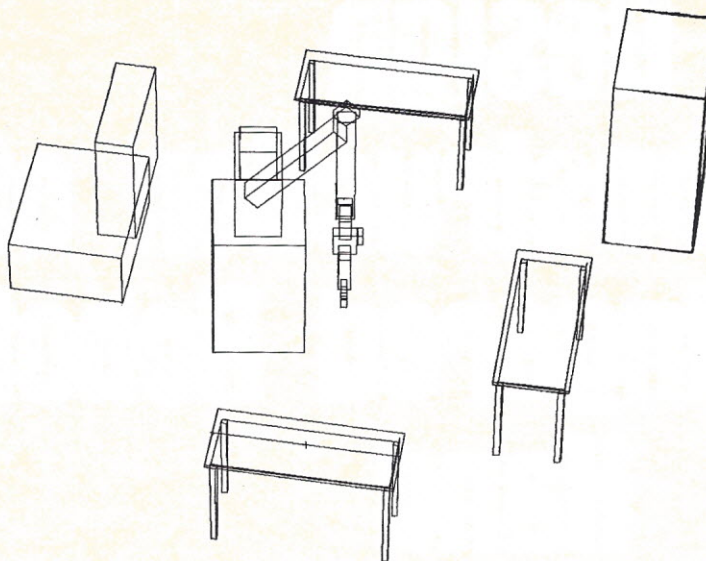


Figure 3. A simulation of a Cincinnati Milacron T3 robot arm. Once the motions of the simulated arm are defined, the motions can be translated into data which are used to directly program the T3.



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Figure 4. Both the Unimate Puma shown here and the Cincinnati Milacron T3 shown in figure 3 have been programmed using a simulated robot and workstation. Programming the robot directly from information generated by a GRASP simulation allows new motion sequences to be designed without disturbing the current robot operations.

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Design and Construction of a Five-Fingered Robotic Hand

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Department of Mechanical
and Industrial Engineering
Clarkson College of Technology
Potsdam, New York 13676

Robotics experts generally agree that a three-fingered hand is sufficient for most manipulative purposes; however, certain tasks that human hands can perform are too sophisticated for a three-fingered hand. For this reason, and because simulating the human hand was an exciting challenge, we designed a five-fingered robotic hand that uses stepper motors controlled by a computer. This project was a part of the industrial robotics research program at the Clarkson College of Technology.

Design Considerations. For simplicity and to ease construction, we designed a hand almost twice the size of an average human hand. We envisioned small motors at each joint, but soon realized that this would be impractical. We then considered using pneumatic actuators at each joint. This would have worked well, but the cost was exorbitant. We finally decided to use cables that could be pulled by remote stepper motors or digitally controlled linear actuators.

The next problem to consider was how to move the fingers with these cables. We decided to use springs to open the fingers, since the hand's strength would be required only when gripping. Next we considered methods for closing the fingers. Our first idea was to just pull the cable and have the finger "fold up" from the tip joint to the

knuckles. We abandoned this method, however, because it would not allow the desired amount of operational control. We considered using the cable to turn a gear fixed to that joint, but that seemed too complex.

We finally decided to wrap the cables around pulleys that would be fixed to each finger joint. To test the idea, we designed and built a test finger (figure 1, photos 1 and 2).

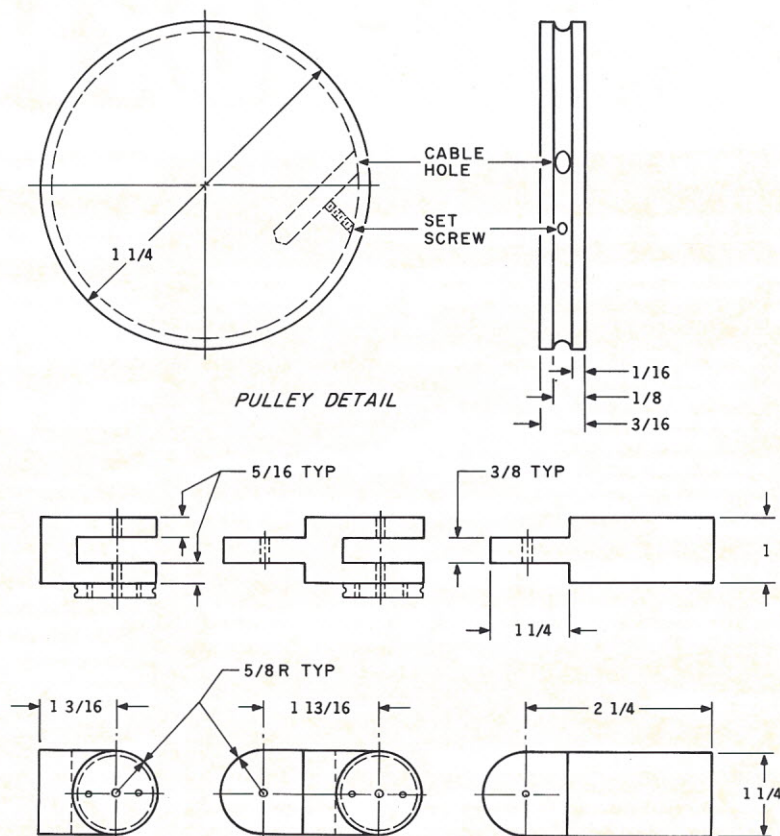


Figure 1. Design details of the test finger, also showing the pulley arrangement that closes the finger.

Once we built the test finger, a major problem arose—getting the finger to close properly. Initially, both cables were pulled at the same velocity; however, the second joint did not close relative to the first. To make the second joint close relative to the first, and at the same rate as the first joint closed relative to the fixed segment, the linear velocity of the second cable had to be twice that of the first cable. These velocities could be produced by one motor, provided that the pulley attached to the motor shaft for the second cable was twice the diameter of the pulley for the first cable. Once we solved this problem, we could build the remaining fingers with no difficulties.

Besides having different lengths, and except for the addition of another joint, the other fingers were similar to the test finger. The pulley design remained unchanged. The second and third joints are shown in figure 2, and the first joints are shown in figure 3. The cables run down the side of the fingers through screw eyes.

The next group of parts to be designed were the hand parts. We designed the knuckles (figure 4) to allow ample space for the pulleys and cable guides between the fingers. There is a two-degree angle between the first and second fingers, and a one-degree angle between the third and fourth fingers. These angles give the fingers some transverse flexibility. We cut and drilled the knuckles and pinned the fingers to them. Then the knuckles were equipped with steel pins inside the frame. The remaining hand parts are shown in figures 5 and 6. The part on the left side of figure 5 holds the thumb.

The Thumb Design. Designing the thumb was difficult, because the human thumb is quite complex. It essentially has three joints, one of which is at the base of the hand, near the wrist. This joint is extremely difficult to model exactly because it allows multi-directional motion, and because it is directly tied in with the bones of the hand at the wrist. We had to decide what motions were most important for the requirements of the robot.

We concluded that the thumb had to be able to close completely; that is, it had to be positioned over the palm to allow the remaining thumb joints to close and form a grip similar to the human grip. The thumb also had to be able to get out of the way of the fingers when necessary. The first joint

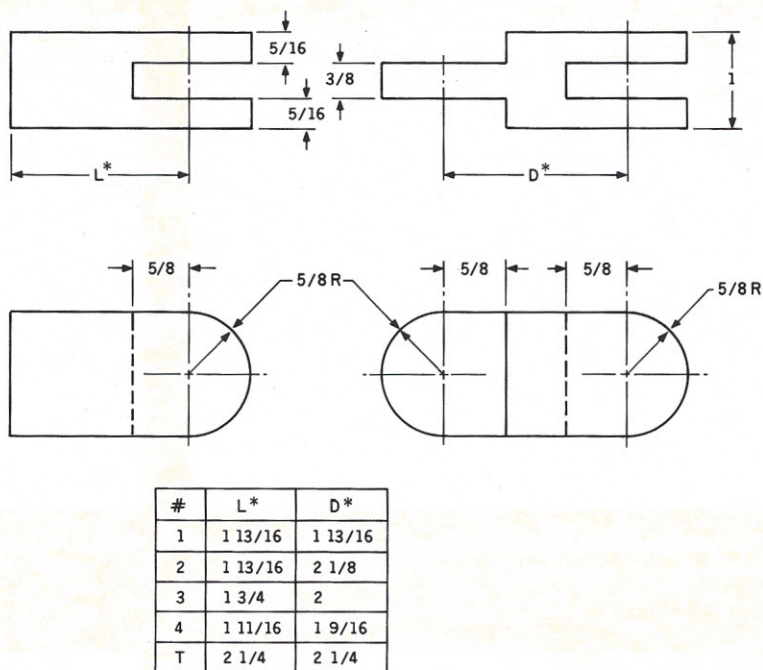


Figure 2. Details of the second and third joints for the fingers and for the thumb. Each finger and the thumb were built to the dimensions listed.

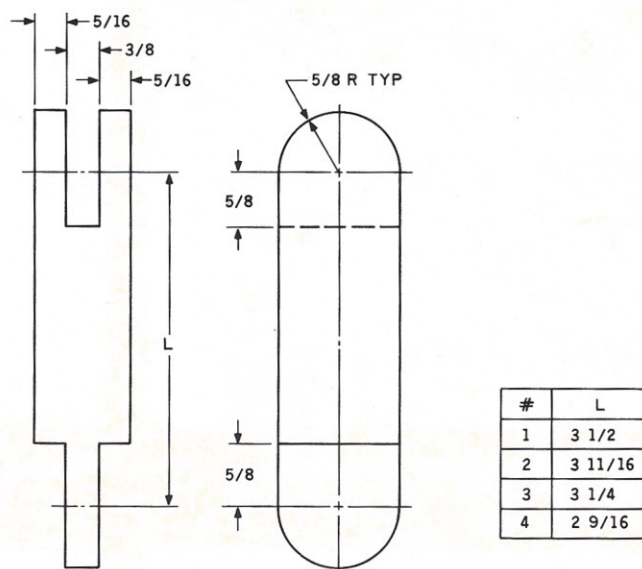


Figure 3. The first joint of all the fingers. Each finger was built to the dimensions listed.

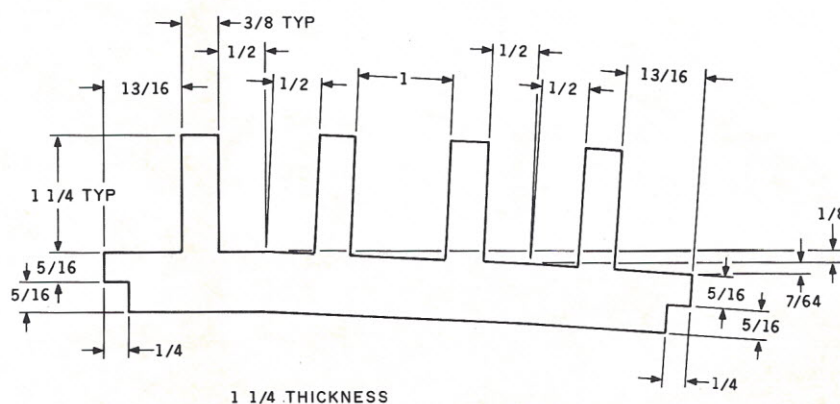


Figure 4. Details of the knuckle design. The knuckles were designed with ample space for the pulleys and cable guides.

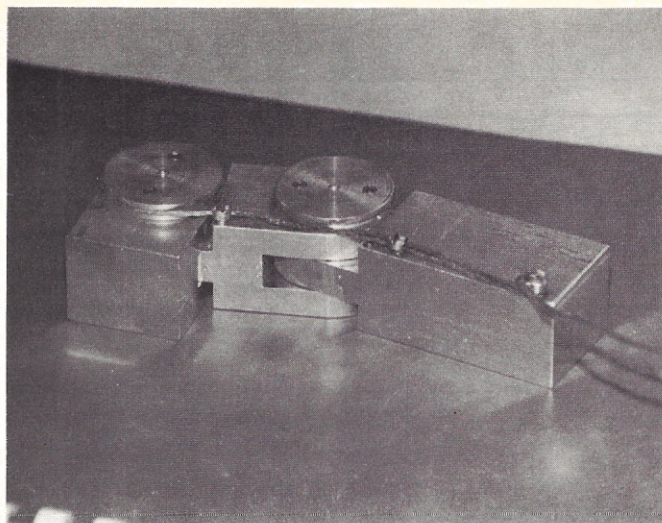


Photo 1. The inside of the test finger. The two pulleys that guide the finger-closing cable are on the top side of the finger.

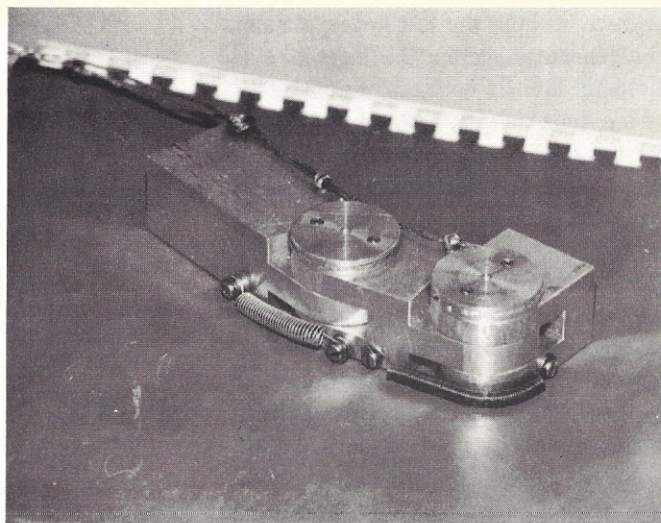


Photo 2. The outside of the test finger. Note the spring that opens the finger.

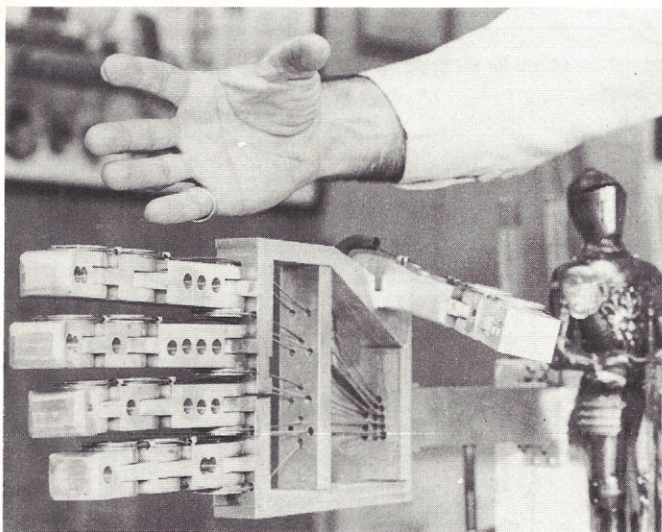


Photo 3. The five-fingered robotic hand, as seen from the palm side. The finger-closing cables are clearly visible.

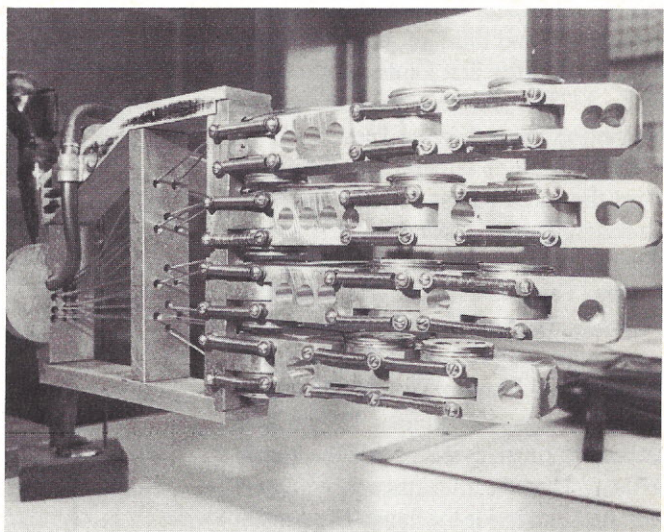


Photo 4. A view of the back side of the hand.

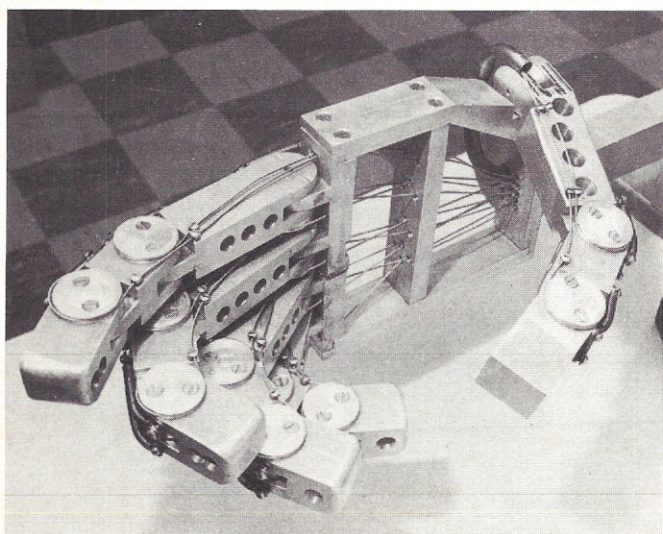


Photo 5. The hand in a half-open position.

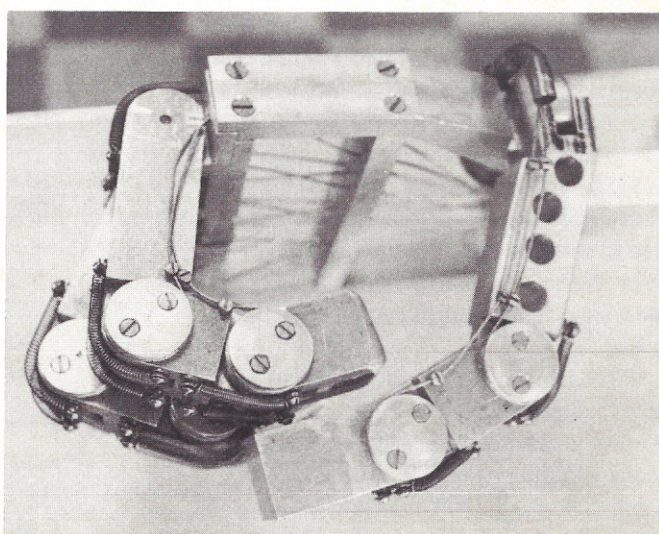


Photo 6. The hand in an almost-closed position.

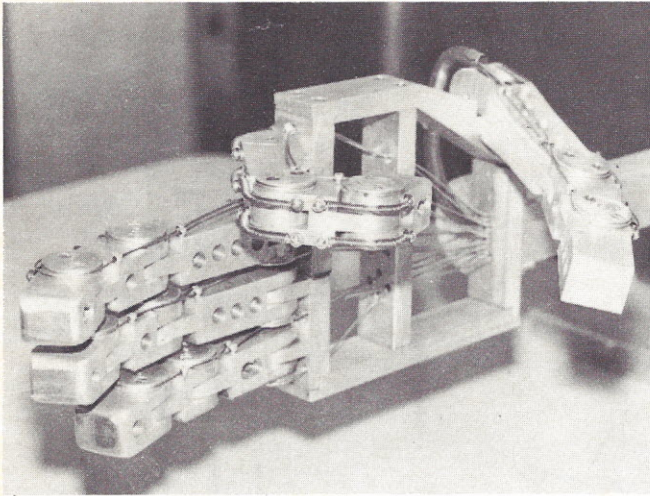


Photo 7. The hand with its first finger closed.

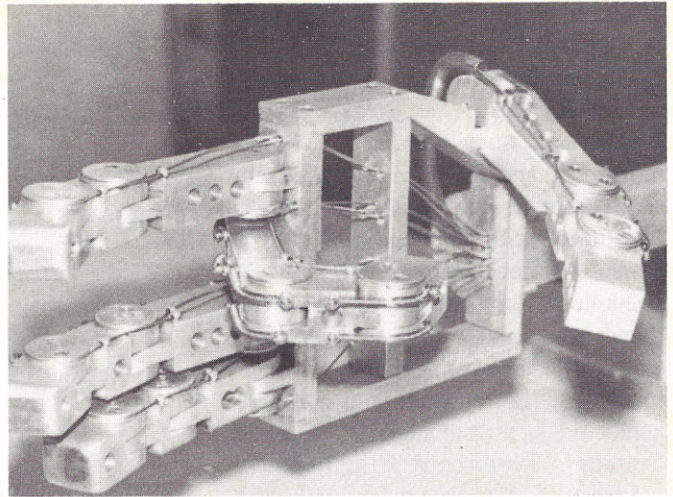


Photo 8. The hand with its second finger closed.

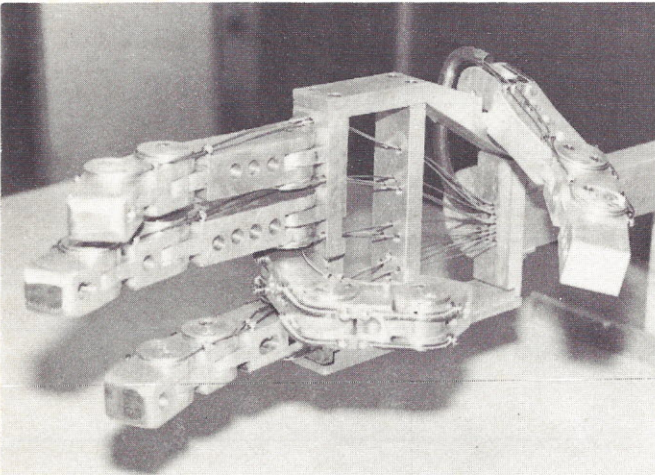


Photo 9. The hand with its third finger closed.

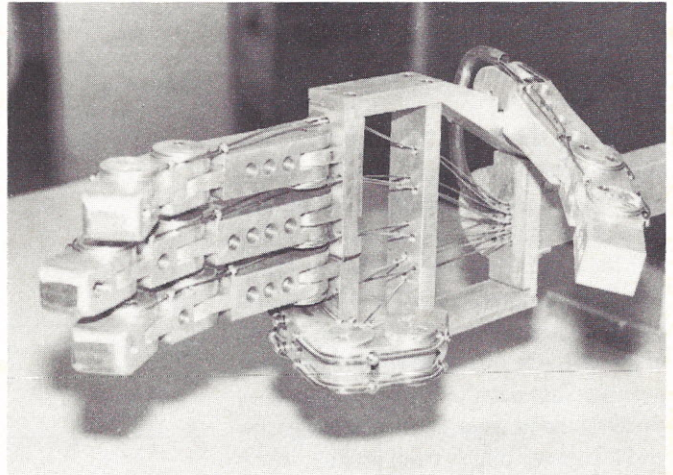


Photo 10. The hand with its fourth finger closed.

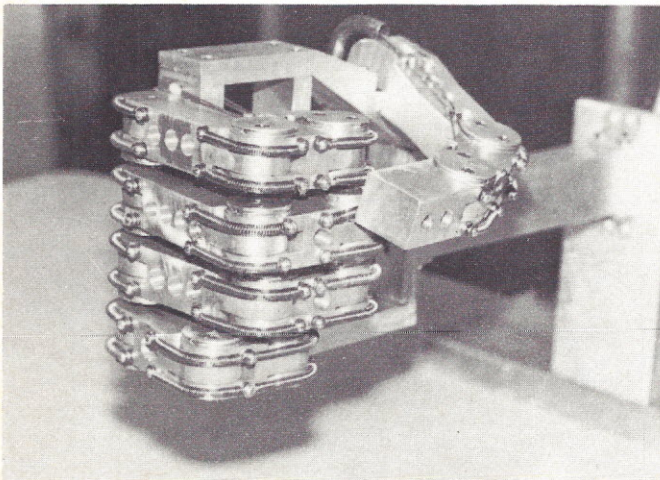


Photo 11. A view of the hand with all fingers closed.

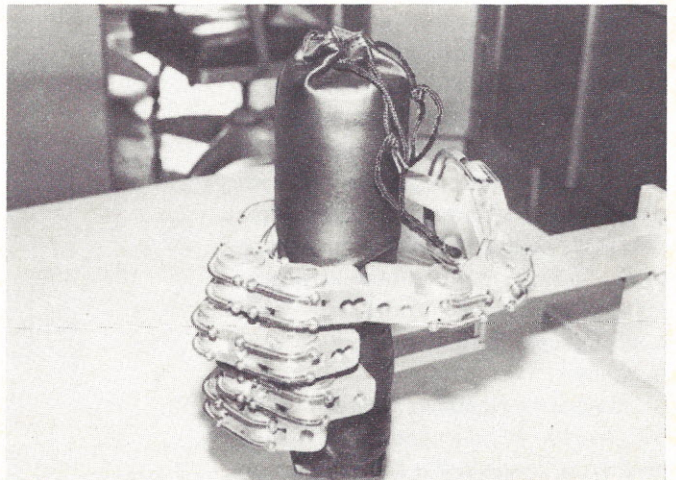


Photo 12. The hand grasping an object.

of the thumb, therefore, had to allow rotation in two planes—one to position the thumb over the palm, and one to allow the remaining joints to close over the fingers.

The design that we settled on is shown in figures 2 and 7. Except for the dimensions, the joints in figure 2 are identical to the finger joints. The joints in figure 7, however, are noticeably different. The pivot point on the right side of the joint lets the thumb close over the palm; the pivot point on the left side lets the next joints close over the fingers. The thumb's built-in 20-degree angle, and the built-in angles of 20 and 30 degrees in the piece that the thumb is mounted to, are required to make the thumb work more like a human thumb.

A key design difference between the thumb and the other fingers is that the thumb should be able to close and open over the palm under power. Since this would have required a modified pulley design, however, we decided to build the prototype hand with the thumb fixed in the bent position (closed over the palm).

Designing the Wrist. The wrist was designed to use standard, commercially available parts, and the only requirement we made of it was that it should be able to roll the hand. The piece shown in figure 6 is incorporated in the hand as an end piece. Figure 8 shows two essential parts of the wrist, the two pipes and the two bearings. Not shown in the figure are a spur gear, which would be fixed around the large pipe, and the motor-pinion combination, which would be fixed to a plate welded to the small pipe. The small pipe guides the cables and is welded to the forearm at two points. From there, it passes through the two bearings and is press-fitted to them.

The large pipe is welded to the end piece of each hand. It is held by a light press-fit to the first bearing. The second bearing is press-fitted directly into the end piece of the hand. The motor-pinion operates the wrist by rotating the spur gear, which in turn rotates the hand through the large pipe. One space between two of the spur gear's teeth is filled in to prevent the wrist from rotating more than 360 degrees, which would cause cables to wrap around themselves.

Although the remaining parts of the arm, from wrist to shoulder, are not described here, an overview of the arm is shown in figure 9. The elbow could be operated by a worm gear arrangement, with the motor

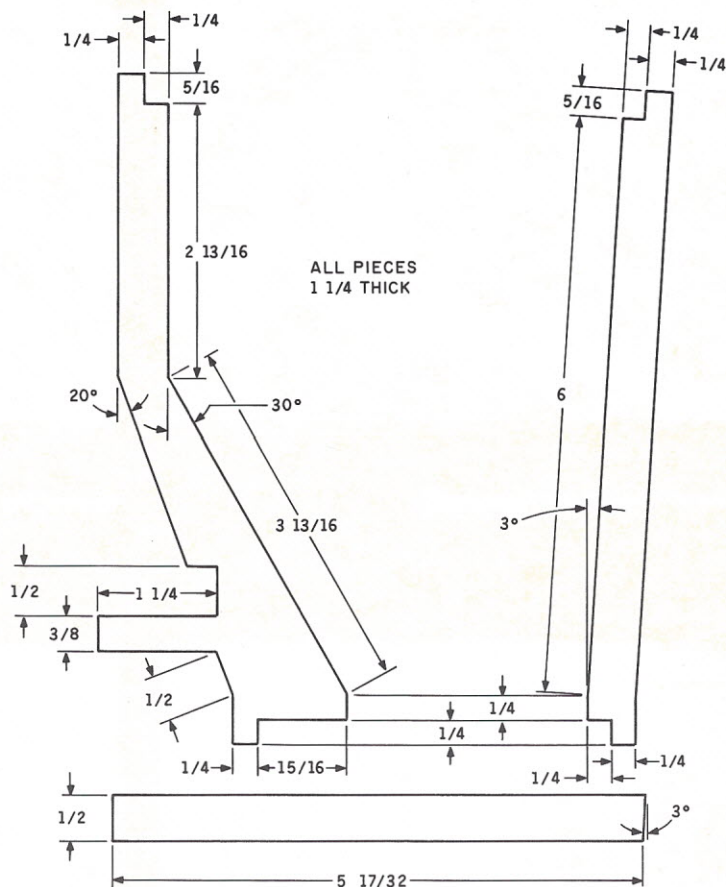


Figure 5. Miscellaneous hand parts. The part on the left was designed to hold the thumb.

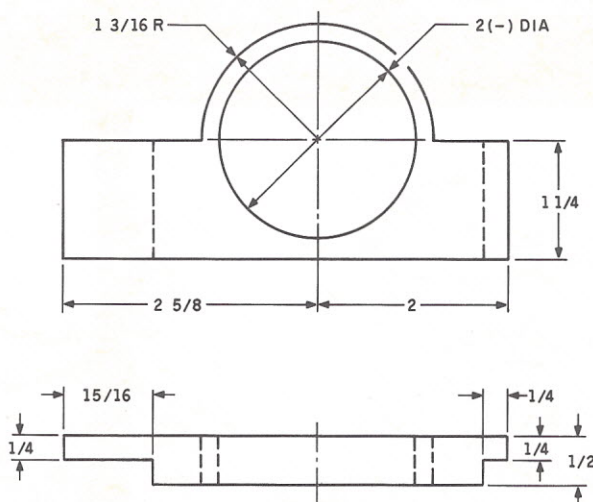


Figure 6. Details of the hand's wrist joint.

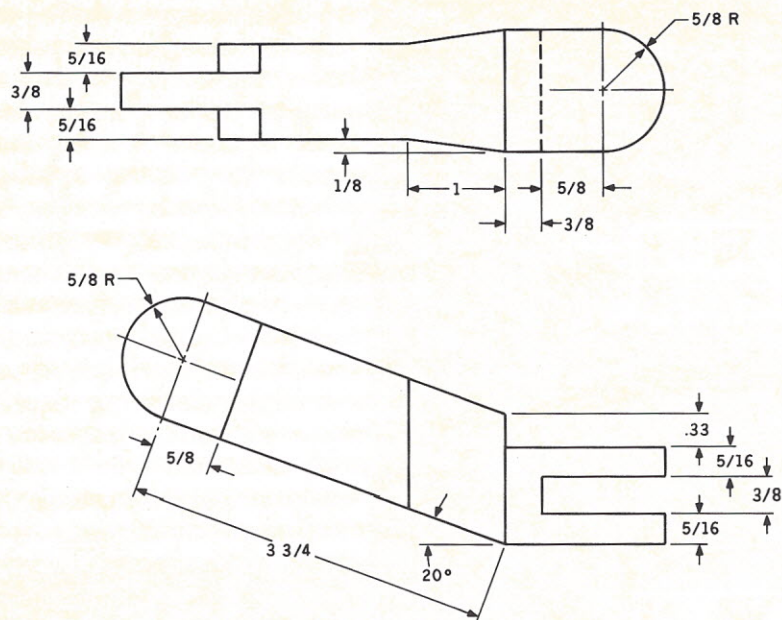


Figure 7. The first joint of the thumb.

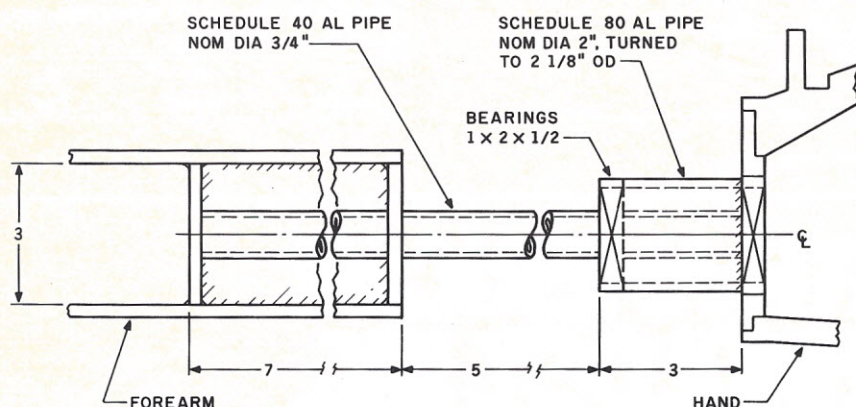


Figure 8. Another view of the wrist joint, showing the two pipes and the two bearings. The small pipe guides the cables and is welded to the forearm at two points.

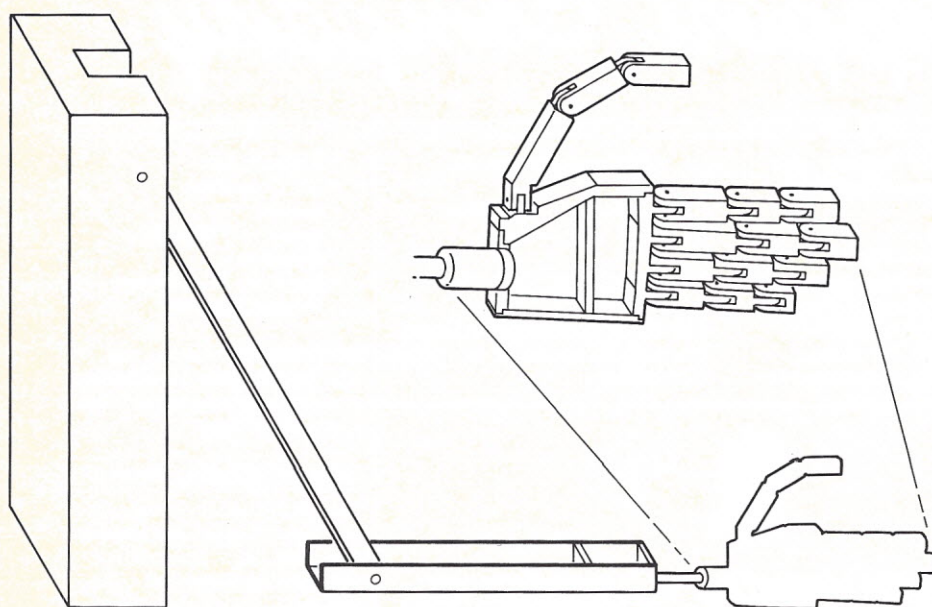
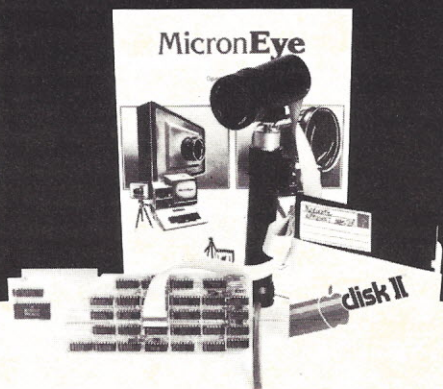


Figure 9. Isometric drawing of the entire arm (no scale). The large box on the arm houses the motors that operate the fingers.

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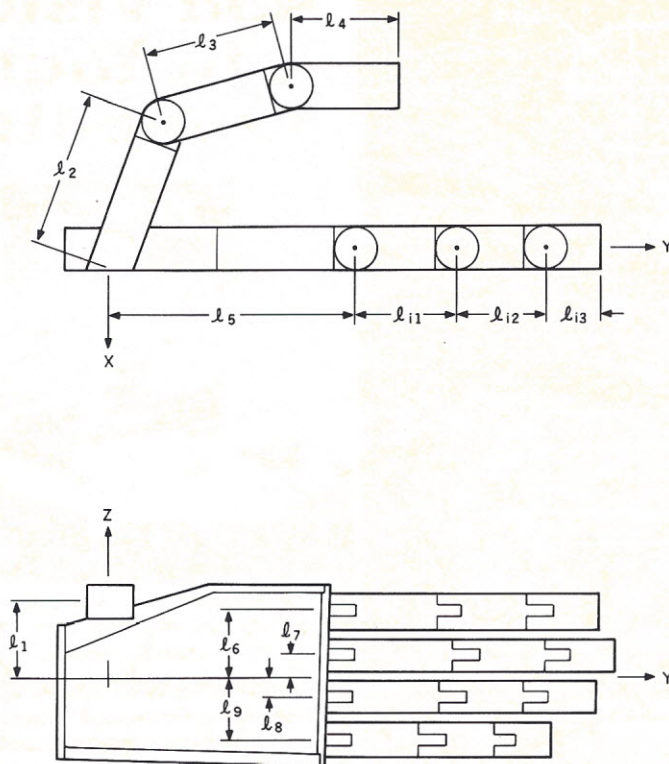


Figure 10. Side and front views of the five-fingered robotic hand.

and the worm attached to the upper arm, and the worm gear fixed to the forearm. This arrangement could also be used to operate the shoulder. The large box, or trunk, on the arm is used to house the motors that operate the fingers. To increase the mobility of the arm, the base of the trunk could be given a waist rotation.

This project was intended to complement bond-graph analytical modeling of sophisticated robotic manipulators. The knuckle motion of the specially designed fingers is created by cables and pulleys with interdendritic hinge joints. The cable motions are then numerically controlled by either stepper motors or digitally controlled linear actuators. The photographs show some detail of the hand's construction. □

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Omnidirectional Vehicle

RUSS ADAMS

The July/August 1983 Patent Probe struck a responsive cord. That column looked at patent number 4,258,815 for an Ambulatory Platform. Many people called or wrote for further details about this invention. The Ambulatory Platform is one of several highly-maneuverable wheeled vehicle patents found in the files of the United States Patent and Trademark Office. An earlier example of this type of vehicle is patent number 4,237,990 issued to Hau T. La on December 9, 1980.

From Toys to Wheelchairs. The patent discloses an "Omnidirectional Vehicle" provided with three individually-driven wheels rotatable on horizontal axes. The invention may be used in a passenger carrying vehicle. Such a vehicle can be used as an amusement bumper car or a protectively shielded car for moving around in a hot cell. Remotely controlled toys or game pieces can also use the three-wheeled system. The high maneuverability allows such toys to move easily into spaces on a game board. The patent, however, is specifically described in terms of a wheelchair for physically handicapped persons.

The La invention uses three wheels, each placed at the corner of a triangle. One wheel's axis forms an angle with another wheel's axis. A vehicle using the La system has true omnidirectionality and directional stability. True omnidirectionality is the ability of a vehicle to move in any direction or to rotate about any point on a given surface without sliding. Directional stability is a characteristic of plural-wheeled vehicles in which there exists only one possible vehicle motion for every given set of wheel rotations.

Variable Roller Configurations. Figure 1 shows a wheel which has eight spokes radiating from a central hub. Eight rollers are mounted around the wheel's periphery. Each roller has an arcuate surface which conforms to the wheel. There will be some bouncing as the rotating wheel rolls from one roller to the next. The rollers are made of rubber to provide traction and dampen

the bounce. More than eight rollers can be used, but of course the expense of construction will increase.

Figure 2 shows an alternative roller configuration which eliminates the bouncing movement of the wheel of figure 1. The rollers are mounted at an angle of about

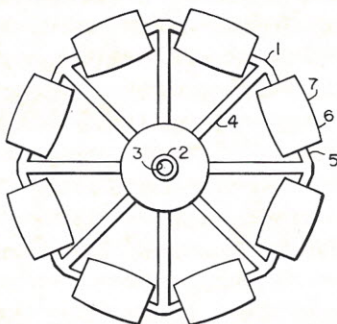


Figure 1: A front elevational view of a wheel defined by the La patent.

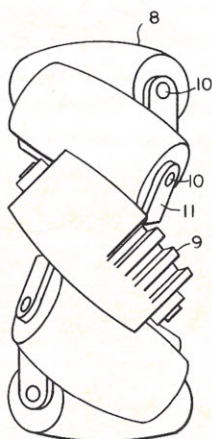


Figure 2: A modification of the roller mounting. Each roller is mounted at an angle with respect to the wheel's axis.

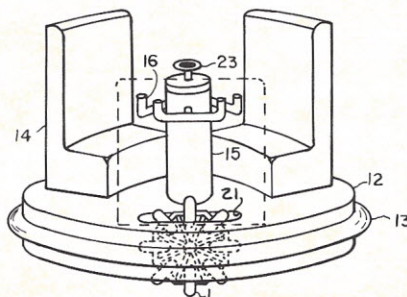


Figure 4: A perspective view of a bumper car. One seat has been removed to show how a wheel is positioned.

45 degrees with respect to the wheel's axis. As one roller leaves the ground, the next roller makes contact.

Three-seat Bumper Car. The bumper car shown in figure 4 is composed of a circular platform (12) surrounded by a resilient bumper ring (13). Three inwardly facing seats (14) are mounted to the platform. Three control handles (16) are mounted to a central post (15). These handles move potentiometers for controlling the action of drive motors for each of the three wheels.

The drive motors (19) are shown schematically in figure 5. Each wheel is mounted

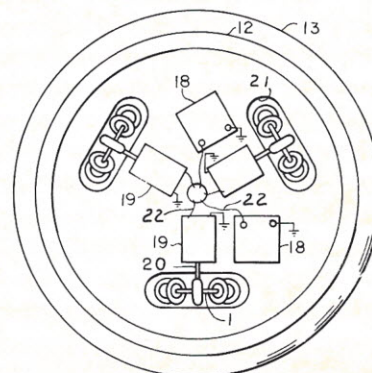


Figure 5: A bottom view of the bumper car with the drive motors, battery, and controls shown schematically.

to the respective shafts of the three motors. The platform can include cut-outs (21) to provide clearance for the wheels. Each wheel would then extend up through the cutout into a hollow space under each seat. Electrical wiring from the batteries (18) and the motors extend up through the central post and are connected to the control potentiometers.

The bumper car motion is related to the rotational speed of the wheels by the equations:

$$\begin{aligned} r\omega_1 &= v_x + R\omega \\ r\omega_2 &= -0.5v_x + 0.866v_y + R\omega \\ r\omega_3 &= -0.5v_x - 0.866v_y + R\omega \end{aligned}$$

Using an orthonormal coordinate system of axes fixed with respect to the body of the vehicle and in the plane of the platform, the variables are defined as follows:

- v_x and v_y are respectively the x and y components of the translational velocity of the vehicle
- ω is the rate of rotation of the vehicle around its center
- ω_1 , ω_2 , and ω_3 are the rates of rotation of the three wheels
- r is the wheel radius
- R is the distance from the center of the vehicle to the center of the wheel

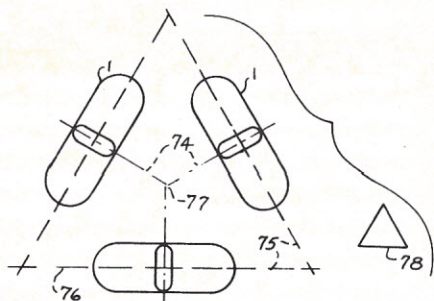


Figure 11: Schematic diagram of the footprint is shown which corresponds to the wheel system of figure 1.

If the wheels are of equal radius and equidistant from the center of the vehicle, r and R will be the same value and will simplify the equations. The system of coordinates is chosen so that the origin lies at the center of the vehicle. The center of one wheel is chosen to lie on the negative y axis. This places the second wheel in the first quadrant $(+x, +y)$. The third wheel will then be in the second quadrant $(-x, +y)$.

If the x, y, and z output voltages of the potentiometers have the same range of

values, the wheel drive motors may be controlled by relating their drive voltages as follows:

$$V1 = Vx + 0.5Vz$$

$$V2 = -0.5Vx + 0.866Vy + 0.5Vz$$

$$V3 = -0.5Vx - 0.866Vy + 0.5Vz$$

In the circuit of figure 14, slider 64 on resistor 62 is connected through a resistor to the negative terminal of the operational amplifier 92. The operational amplifier 92 is configured as a unity gain inverter by means of a feedback resistor. The positive input terminal is grounded. A power supply is connected to the amplifier in such a way that terminal 96 is at a potential of +15V while terminal 97 is at -15V with respect to ground. With such a configuration, the amplifier will invert the input voltage Vx as required to satisfy the algebraic relationship.

Slider 64 is also connected via a resistor to the negative terminal of an operational amplifier 71 which provides the drive voltage $V1$. Slider 65 is connected via a resistor to the negative terminal of amplifier 102. The output of amplifier 92 is via 200k ohm resistors to amplifiers 72 and 73. Slider 64 is further connected via a 115.5k ohm resistor to terminal 106. Terminal 103 is connected by a 115.5k ohm resistor to terminal 107.

In addition to the translational voltages $V1$, $V2$, and $V3$, a rotational component is added to each voltage by action of slider 69. Slider 64 is connected by 200k ohm

resistors to terminals 99, 106, and 107 respectively.

Further Reading. Other highly maneuverable vehicles have been proposed. Some of these prior vehicles are exemplified by the following U.S. patents: 3,789,947, "Omnidirectional Wheel," to Blumrich; 3,253,632, "Resilient Wheel," to Dalrymple; 1,305,535, "Vehicle Wheel," to Grabowiecki; 3,876,255, "Wheels for a Course Stable Self-Propelling Vehicle Movable in any Desired Direction on the Ground or Some Other Base," to Ilon; 3,295,700, "Method and Apparatus for Handling Radioactive Materials," to Ziegler; 3,465,843, "Vehicle with Improved Steering Device," to Guinot; 3,746,112, "Directionally Stable Self-Propelled Vehicle," to Ilon; 3,420,326; "Land Vehicle Propulsion," to Kusmer; and 3,570,615, "System for Controlling the Application of Motion of Vehicle Wheels," to Guilbaud. □

Copies of Patent 4,237,990 and the other patents mentioned are available from the U.S. Patent and Trademark Office for \$1.00 each. Orders for patents should be sent with payment to: Commissioner of Patents and Trademarks, Washington, DC 20231.

The illustrations in "Patent Probe" are reproductions of diagrams in the original patent documents.

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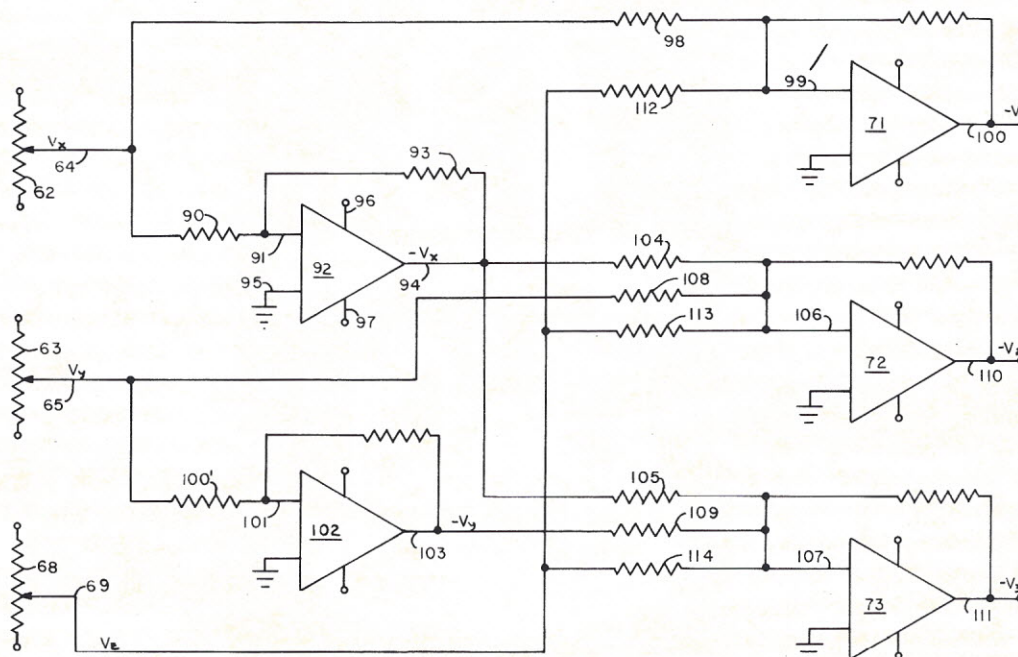


Figure 14: A detailed schematic of the control circuit for the three-wheeled vehicle.

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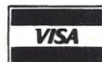
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Using Microprocessors with Radio-Control Servos

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Microprocessors are often used to control motors. Many common motor-control methods, however, are expensive, complicated, or both. Stepper motors require complex control circuitry, and their voltage requirements often dictate a custom power supply. Their low output torque usually means adding a cumbersome, mechanical gearing arrangement.

A DC motor with potentiometric feedback is a simple alternative, but only if the control signal is an analog voltage. Since microprocessors are digital devices, they require a digital-to-analog converter to control the motor. DC motors also suffer from the same low-torque disadvantage of stepper motors.

The key to a simple motor-control system is recognizing that microprocessors prefer to work in the *time* domain. Even the most simple, single-chip processor can send timed pulses to its output ports. These pulses can be any number of machine cycles long, and the length can contain information about how much mechanical motion is needed.

The radio-control model industry set standards for a pulse-length encoding system for model airplane servos several years ago. Modern radio-control servos are strong, light, high-torque devices that provide either linear or rotational motion, proportional to a pulse signal input. They can

be connected directly to most microprocessor ports without additional components. Table 1 contains the specifications of the Heathkit GD 1205-4, a typical radio-control digital servo; figure 1 illustrates a basic computer-to-servo connection.

How They Work. The typical radio-control servo has a three-wire input. One wire provides +5V power, one is grounded, and the third carries the control signal. The servo examines the positive width of the control pulse to determine the desired position of the motor's output shaft. Widening the

pulse (towards 2 milliseconds) drives the shaft in one direction, while narrowing the pulse (towards 1 millisecond) moves the shaft in the other direction. Figure 2 illustrates this concept. When no pulse is received, the shaft remains stationary. (Actually, unpulsed servos are held stationary by the friction in the motor and the mechanical advantage of the drive train. Some servos could creep slowly under excessive loading.)

The servo senses the rise of the control pulse. This initiates an internal pulse with a length determined by positional feedback

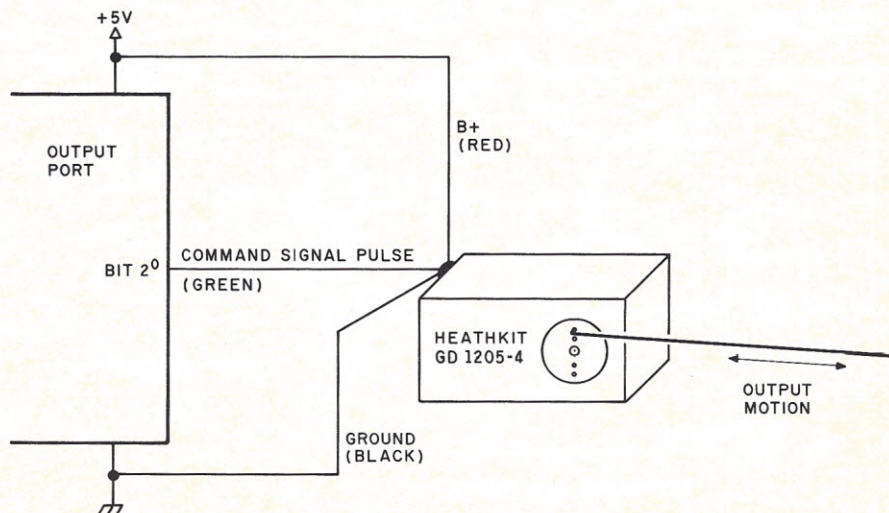


Figure 1. A basic computer-to-servo interface. The servo shown here is a Heathkit GD 1205-4, a typical radio-control digital servo.

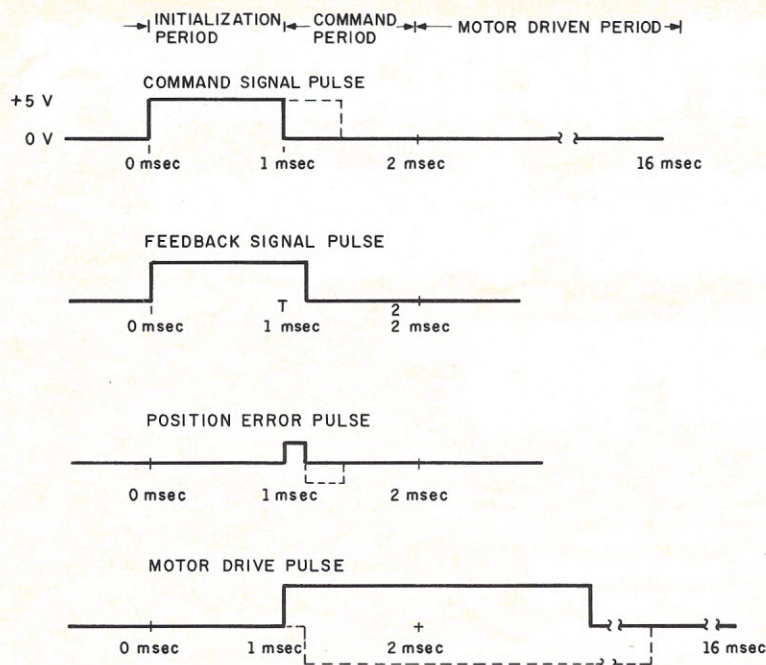


Figure 2. Servo pulse timing diagrams. Widening the control pulse (towards 2 milliseconds) drives the shaft in one direction; narrowing the pulse (towards 1 millisecond) drives it in the other. The error signal, generated by subtracting the control signal from the internal feedback pulse, indicates how far the output shaft is from its desired position.

Force	3 lbs. at wheel
Power	B+ 5 volts (4.8 minimum)
Idle	20 mA
No load	80 mA
Stalled	600 mA
Travel time	0.6 seconds
Rotary output travel	90 degrees rotation.
Position accuracy	1%
Input signal	Pulse: 1-2 msec wide (4V minimum)
Repetition rate	60 Hz nominal
Temperature range	0° to +160°F
Dimensions	H 1 5/8 in.
	W 1 5/16 in.
	L 2 9/32 in.
Weight	1.75 oz.

Table 1. Specifications of the Heathkit GD 1205-4 miniature digital proportional servo, a typical radio-control servo.

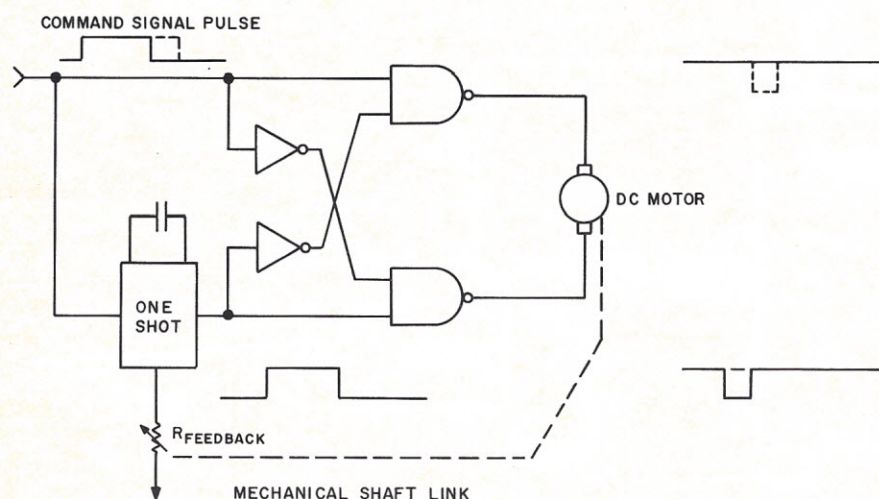


Figure 3. Applying radio-control servo concepts on a larger scale. The NAND gates in this circuit could sink, or source, the motor current, depending on the motor.

from an internal shaft-feedback potentiometer. The control signal pulse is then subtracted from this internal feedback pulse. Their difference results in a positive or negative pulse of varying length. This short pulse, called the error signal, indicates how far the output shaft is from its desired position. This error signal is used by the motor-drive circuitry, which drives the motor proportionally for up to 16 milliseconds during the motor drive period.

Listing 1 is a control routine written in pseudo-assembly language for a processor such as the KIM. This listing assumes that the processor is dedicated to the pulse-generating routine. Interrupts cannot be handled with this "countdown" technique. For highest resolution, the code in lines 5-7 should execute in approximately 1 microsecond; therefore, this routine should not be written in a high-level language. Each servo nominally expects a 14 millisecond motor-drive period. Put another way, it expects a 60 Hz command pulse repetition rate. This allows a single routine to sequentially control up to seven additional servos. The code to control them should be patterned after lines 2-8 and inserted between lines 9 and 10. The DELAY in line 10 should be shortened by 2 milliseconds for each additional servo.

Since uncommanded servos do not move, the restriction of eight servos applies only to simultaneously moving servos. Any number of stationary servos may be connected yet momentarily left uncommanded. More complicated routines could be written that do not rely on the 14 millisecond drive period to overlap other servo commands. The number of simultaneously moving servos would then be limited only by your hardware. Better still, interrupt timers could be used to control many servos simultaneously.

If your mechanical requirements exceed the limits of a model airplane servo, you could apply the same motor-control concepts on a larger scale. Figure 3 shows the conceptual arrangement of this circuitry. As mentioned, an internal pulse is generated with a length proportional to the output shaft position. A problem will occur, however, in most applications of this system. With a maximum length of 1 millisecond, the error output is a pulse too short to be useful. A very high repetition rate would be necessary to drive the servo a significant distance. One alternative stretches the pulse using the motor drive portion of the cycle.

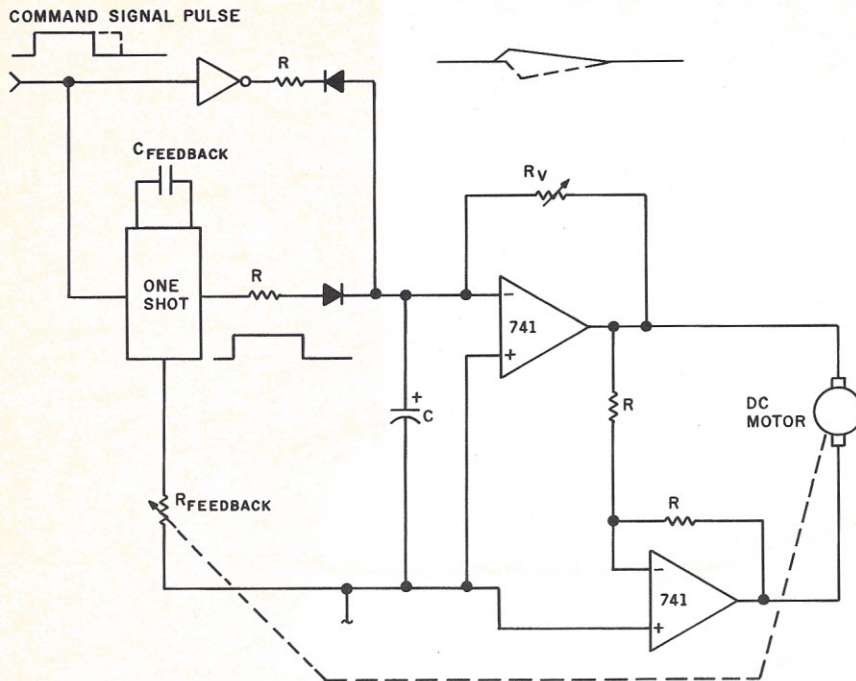


Figure 4. Using the error pulse to charge a capacitor, which is then discharged more slowly by negative feedback from the motor-drive circuitry. The values of R , R_v , and C determine the gain and damping applied to the mechanical system and are found through experimentation. In general, the product of $R \times C$ should create a delay greater than 2 milliseconds, and R_v approximates $16 \times R$. If the operational amplifiers chosen are not capable of supplying the motor starting current, additional amplification must be included. The values of the feedback potentiometer and capacitor should be selected to produce a 1- to 2-millisecond pulse.

```

1  ENTRY  REPETITIONS=60                ;command repetitions per call
2  REPEAT  X=POSITION
3          CONTROL PORT=1
4          DELAY (1) MSEC                ;initialization period

5  LOOP    X=X-1
6          DELAY                          ;such that LOOP times
                                           ;close to 0.01 msec

7          IF (X > 0) THEN GOTO LOOP

8          CONTROL PORT=0                ;end the command pulse
9          DELAY (1-POSITION/100) MSEC   ;complete 2 msec cycle
10         DELAY (14) MSEC                ;complete 16 msec cycle
11         IF (REPETITIONS=0) THEN RETURN ;check for proper number
                                           ;of repetitions

12         DECREMENT (REPETITIONS)
13         GOTO REPEAT
14         END

```

Listing 1. A general countdown routine for command pulse generation, written in pseudo-assembly language. This routine must be called with POSITION containing a two-digit number.

The circuit in figure 4 uses the pulse to charge a capacitor, which is then discharged more slowly by negative feedback from the motor-drive circuitry. The motor-drive pulse then can be an arbitrarily longer version of the error pulse. Theoretically, the pulse-width gain could be adjusted to closely approximate the desired movement on the first command pulse. In practice, the gain is set closer to 16, and the command pulse

repeats 60 times per second. This helps avoid servo oscillations, improves response tracking times, and improves the final accuracy of the system. ☐

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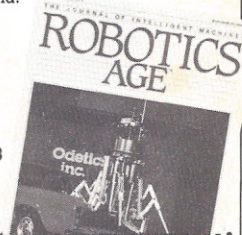
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Editorial

Continued from page 4

capable of handling the graphics and mathematics required. A reasonable estimate for the cost of a hardware/software system is in the \$30,000 range. This is well within the range of many smaller businesses and would open up a new area of service organization, the CAD Service Shop.

Just as the introduction of inexpensive phototypesetting equipment paved the way for small companies which specialized in setting type, an inexpensive CAD system would allow CAD Service Shops to provide mechanical design services.

A customer could present a mechanical design task to the service company and ask for a simulation of several different design options. The CAD Service Shop would return demonstrable simulations of each option along with an evaluation of the defined system's performance. When a particular design was selected by the customer, the CAD Service Shop could also use the computer simulation to generate a list of required materials, a computer-numerically controlled machine tool program, and assembly instructions. Just as many electronic companies contract to outside service organizations to design their printed circuit boards once the electronics are designed, the mechanical manufacturer may soon contract to a CAD Service Shop to provide design instructions once a product idea is conceived.

RARE Errors. The *Robotics Age* Reader Evaluation system was initiated with the September/October issue. RARE allows readers to evaluate the usefulness of published articles and let the editor know what type of information they find most useful.

Many of you took advantage of the first RARE to tell us exactly what you wanted to know. However, the November/December RARE ran into trouble. The following letter received from Lon R. Stockton, Jr. says it all.

"Gentlemen. Without meaning any disrespect to your fine magazine, and to inform you of a manifestation of Murphy's Law; I should like to inform you that the Reader Service card number for 'Forethought Products' (p.35) and the number for RARE (FAIR, p.46) are the same. Oh, well. If that's the best error you people can come up with, you'll go far in the business."

This error is repeated throughout the table of single-board computers and RARE evaluations for articles. To handle this problem, we scanned the Reader Service cards looking for patterns. Most people seemed to be looking for information about the single-board computers and not evaluating the articles. As a result, everyone who circled a number corresponding to a single-board computer company will receive information about that computer.

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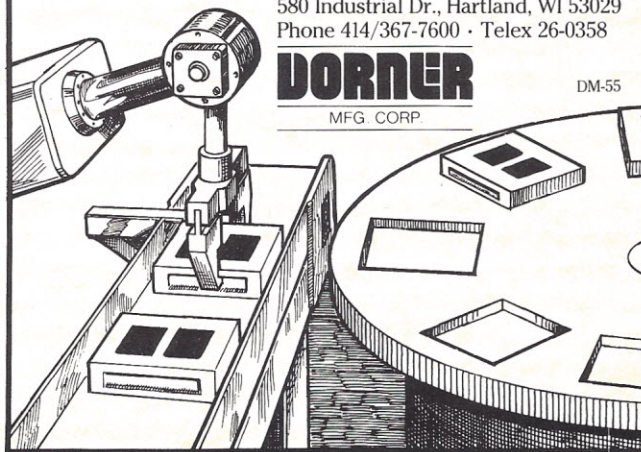
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Designing a Reliable Voice-Input Robot Control Language

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Conventional approaches to manipulator control are based either on concepts borrowed from programming languages with data structures and primitives appropriate to the task, or on the operator's intuitive understanding, translated through the medium of a teach pendant. In the first case, the abstract world of coordinate frames is used to guide the robot; in the second, the operator must observe the manipulator and the teach pendant simultaneously. An alternative, experimental approach uses a speech-input device for robot control, thus allowing the user to keep his or her attention fixed on the manipulator during the training session.

The program described in this article was developed by the robotics group at the University of Illinois as a prototype of a device-independent, voice-input robot control language. The development version was implemented on an Apple II microcomputer, using a Heuristics Speechplot card for voice input. This card is no longer available; however, the concepts presented here apply to any similar voice-input system.

The target robot was a Rhino XR-1, an educational robot powered by servomotors and guided by an Intel 8748-based controller. (More detailed descriptions of the Rhino XR-1 can be found in the March/April 1982, the September/October 1982, and the January/February 1983 issues of *Robotics Age*.)

A Word About the Speech Card. The Heuristics Speechplot card has a programmable vocabulary of 32 words. The operator trains the board by speaking each word to be learned. The card samples the 1000 to 4000 Hz portion of the audio spectrum and converts each word to digital form using the word's high frequency, low frequency, and overall energy components. Word length is limited to 1.25 seconds; words are separated by 0.25 seconds of silence. Once spoken, the word is associated with a string or numeric variable.

When a word is spoken, the card attempts to match the input pattern with the stored samples using a rough averaging process. When a match is found, the corresponding

string or numeric value is returned to the controlling program. Accuracy with this type of device ranges from 60 to 80 percent. This rate is decreased by the types of words that can be expected in this application. Our machine, for example, might be expected to respond to commands such as left, right, up, and down. These words are short and, except for down, end abruptly (with large high-frequency components). Because of the card's small frequency sample space, the error rate for these and similar words is high.

We achieved better results (70 to 90 percent accuracy) with a vocabulary tailored to the characteristics of the Speechlab board. Words borrowed from the Romance languages tend to have a longer and better-defined sample space; therefore, left was replaced with *gauche*, right with *droit*, ahead with *avant*, and behind with *arriere*. (As a rough guide, these words are pronounced *gosh*, *duwah*, *avahn*, and *ah-ree-air*, respectively.) The English equivalents appear in the program displays; the operator simply speaks them in French.

Designing the Command Set. We designed commands that rotate, raise, and lower the end effector, and permit opening and closing the fingers. We also included commands to move the robot from one position to the next. They are RIGHT, LEFT, HIGHER, LOWER, AHEAD, and BEHIND. Their effects, illustrated in figure 1, are as follows:

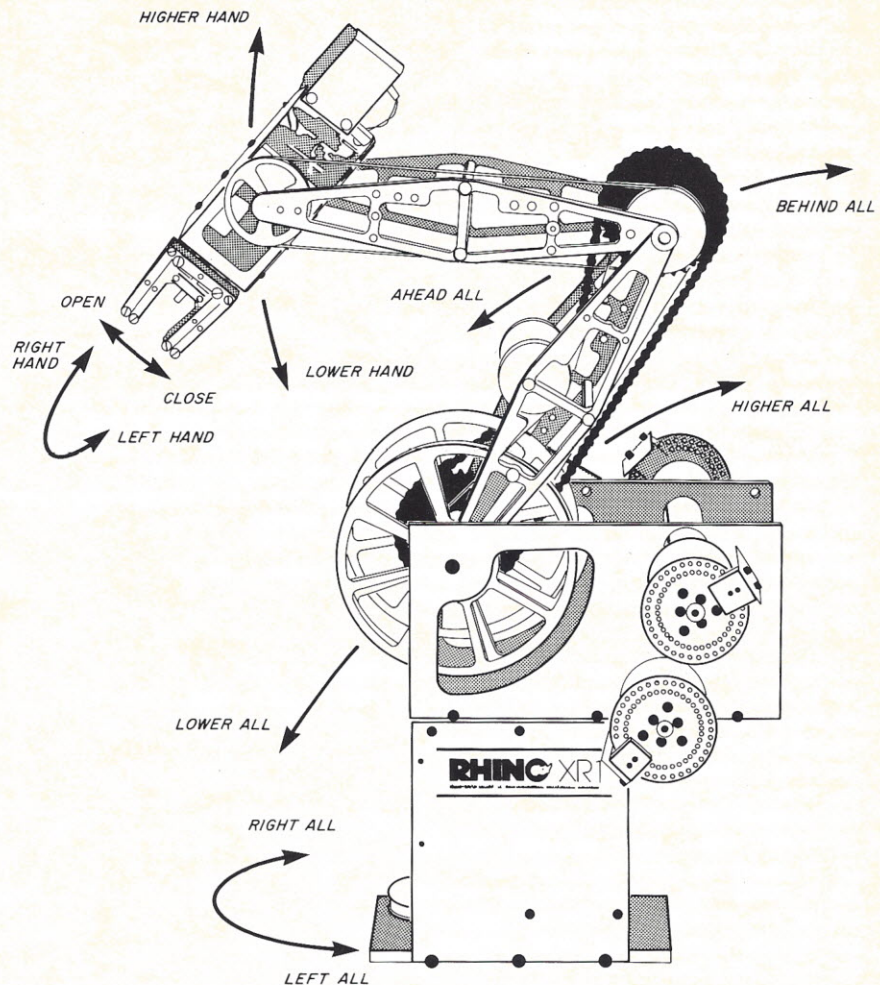
- RIGHT and LEFT move the base as you would expect
- HIGHER moves the shoulder toward the rear of the robot, keeping the shoulder-elbow angle constant.
- LOWER moves the shoulder forward while retaining the shoulder-elbow angle
- AHEAD moves the shoulder to the front and increases the shoulder-elbow angle
- BEHIND moves the shoulder to the rear and reduces the shoulder-elbow angle.

Because of the input device's low reliability, we developed a control strategy where the number of the robot's commands is limited, depending on the context, or mode, that is set. The CHANGE command alters the mode and, therefore, the currently recognized command set.

We partitioned the robot into two coordinate frames, designated ALL and HAND. The ALL coordinate frame consists of the principal axes—the base, elbow, and shoulder; the HAND frame deals with the end-effector only—rotating it, and opening and closing the fingers. The commands RIGHT and LEFT result in different actions, depending on which mode is set. The AHEAD command is not recognized in the HAND mode, and the OPEN and CLOSE commands are invalid in the ALL mode.

Three additional commands are valid after the CHANGE command. The ENTER command permits the entry of a move, the RUN command executes a move sequence, and the HOME command returns the robot to its starting configuration and automatically constitutes an additional move. Before the RUN or HOME command is executed, the operator must verify his or her request by typing Y and pressing the return key.

Language Summary. The control structure of this language operates on the principle of partitioning the recognized commands for the three available modes, thus decreasing the margin for error. Each mode has a limited number of options within it and, if an illegal request for a given mode is returned by the speech card, the input is



Legal commands and their effects in the ALL mode

- RIGHT — moves base to the right
- LEFT — moves base to the left
- HIGHER — moves shoulder toward rear; maintains shoulder-elbow angle
- LOWER — moves shoulder forward; maintains shoulder-elbow angle
- AHEAD — moves shoulder toward front; increases shoulder-elbow angle
- BEHIND — moves shoulder to rear; decreases shoulder-elbow angle

Legal commands and their effects in the HAND mode

- RIGHT — rotates hand clockwise
- LEFT — rotates hand counterclockwise
- OPEN — opens fingers on hand
- CLOSE — closes fingers on hand
- HIGHER — raises hand
- LOWER — lowers hand

Legal commands and their effects in the CHANGE mode

- ALL — switches to the ALL coordinate frame
- HAND — switches to the HAND coordinate frame
- ENTER — permits the entry of a move
- RUN — executes the move sequence stored in memory
- HOME — returns the robot to its starting configuration

Table 1. A summary of the robot-control language command words. Note that the RIGHT, LEFT, HIGHER, and LOWER commands have different effects, depending on the mode that the system is in.


```

10 POKE 74,124: POKE 204,124: POKE 75,21: POKE 205,21:SLOT=4
11 REM SET LOMEM TO 5500
12 PRINT "":"BLOAD RESET,A$9200"
13 PRINT "":"BLOAD ALLMOS,A$9000"
14 REM LOAD ASSEMBLY LANGUAGE DRIVERS
15 REM HIMEM = -32513
20 PR#SLOT: PRINT : PR#0
16 REM INIT VOICE BOARD
25 CALL -936 : REM CLEAR SCREEN
30 DIM I$(90): DIM Q$(5)
35 I$="" LEFT RIGHTHIGHER LOWER AHEADBEHIND OPEN CLOSE HOME CHANGE ALL HAND RUN ENTER "
36 REM TRAINING EPISODE BEGINS
40 FOR I=1 TO 2
50 FOR J=1 TO 14
60 VTB 10: PRINT "SAY ";I$(J*6-5,J*6);" FOR ME"
70 PR#SLOT: PRINT J: PR#0: FOR K=1 TO 300: NEXT K
90 NEXT J
100 NEXT I: CALL -936: REM END TRAINING EPISODE AND CLEAR SCREEN
105 S1=-28672 : REM ADDRESS OF 'ALLMOS' RHINO DRIVER; SB= LOAD ADDRESS OF SIGN BYTE
110 SB=S1+301:HB=SB+8:LB=HB+8:CT=0:P= ASC("+")-128:M= ASC("-")-128
115 REM HB= HI BYTE LOC FOR DRIVER, LB = LO BYTE LOC FOR DRIVER (1 OF 8)
120 DIM TP(8): DIM TM(8):BU=-32512:BH=BU+768:BL=BH+768: DIM T(8):SF=BU:HF=BH:LF=BL:CT=BL+767
125 REM TP=STORAGE OF POS STEPS IN CURRENT MOVE FOR 8 MOTORS
126 REM TM = STORAGE FOR MINUS STEPS WITHIN MOVE
127 REM BU = SIGN GLOBAL BUFFER ($8000) ;BH = HI BYTE GLOBAL ; BH= LO
130 FOR I=0 TO 8:TM(I)=0:TP(I)=0:T(I)=0: NEXT I
150 MD=1

155 REM INIT ARRAYS,SET MODE TO 'ALL', CHECK KEYPRESS FOR EXIT
190 X= PEEK (-16384): IF X= ASC("X") THEN 6050: POKE -16384,0: POKE -16384+16,0
195 GOSUB 3000 : REM GET COMMAND INPUT
196 REM PROCESS VALUE RETURNED (SEE WRITEUP)
200 IF A=10 THEN 4000
210 IF A=9 THEN 1100
220 IF (MD=1) AND (A<7) THEN 290
230 IF MD=2 THEN IF (A>2) AND (A<5) THEN 280
250 IF (MD=2) AND (A<3) THEN 285
260 IF (MD=2) THEN IF (A>6) AND (A<9) THEN 290
265 FOR I=1 TO 10:X= PEEK (-16336): NEXT I
270 GOTO 190 : REM NO VALID INPUT, GET MORE
280 A=A+7: GOTO 290
285 A=A+11
290 REM SET UP RETURNED VALUE ACCORDING TO MODE AND JUMP TO APPROPRIATE ROUTINE
295 GOTO (A+2)*100
300 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE LB+2,(5*16):TP(2)=TP(2)+50: CALL -28672: GOTO 190
400 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+2,M: POKE LB+2,80:TM(2)=TM(2)-50: CALL -28672: GOTO 190
450 REM 300= 'LEFT' (MOVE BASE +50) ; 400= 'RIGHT' (MOVE BASE -50)
500 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+3,M: POKE LB+3,80:TM(3)=TM(3)-50:
550 POKE SB+4,P: POKE LB+4,80:TP(4)=TP(4)+50: CALL -28671: GOTO 190
575 REM 400 TO 450 = 'HIGHER' I. E. SHOULDER GETS +50, ELBOW GETS -50 STEPS
600 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+3,P: POKE LB+3,80:TP(3)=TP(3)+50
650 POKE SB+4,M: POKE LB+4,80:TM(4)=TM(4)-50: CALL -28671: GOTO 190
675 REM 600 TO 650 = 'LOWER', SHOULDER GETS -50; ELBOW GETS +50 STEPS
700 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+3,P: POKE LB+3,80:TP(3)=TP(3)+50
750 POKE SB+4,P: POKE LB+4,80:TP(4)=TP(4)+50: CALL -28671: GOTO 190
775 REM 'AHEAD' SHOULDER GETS +50, ELBOW GETS +50 STEPS
800 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+3,M: POKE LB+3,80:TM(3)=TM(3)-50
850 POKE SB+4,M: POKE LB+4,80:TM(4)=TM(4)-50: CALL -28671: GOTO 190
875 REM 'BEHIND' SHOULDER AND ELBOW GET -50 STEPS, UPDATE TM ARRAYS
900 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+7,M: POKE LB+7,80:TM(7)=TM(7)-50: CALL -28672: GOTO 190
925 REM 'OPEN' FINGERS
1000 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+7,P: POKE LB+7,80:TP(7)=TP(7)+50: CALL -28672: GOTO 190
1050 REM 'CLOSE' FINGERS
1100 VTB 20: TAB 1: PRINT "HOME? ";: INPUT Q$: IF Q$="" THEN 1150: IF Q$(1,1)#"Y" THEN 1150
1105 REM KEYBOARD VERIFICATION FOR 'HOME'
1110 FOR I=0 TO 7: POKE BU+(CT*8)+I, ASC("H")-128: POKE BH+(CT*8)+I,0: POKE BL+(CT*8)+I,0:CT=CT+1
1115 SF=SF+8:HF=HF+8:LF=LF+8: POKE CNT,CT
1120 CALL -28160
1150 VTB 20: TAB 1: PRINT " "
1190 GOTO 190
1195 REM END OF 'HOME' ROUTINE
1200 SN=P:TP(5)=TP(5)+50
1225 REM HAND 'HIGHER' ROUTINE, VALID ONLY IN MODE 2
1250 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+5,SN: POKE LB+5,80: CALL -28672: GOTO 190
1300 SN=M:TM(5)=TM(5)-50: GOTO 1250

```



```

1350 REM HAND 'LOWER' ROUTINE SET SIGN TO -, UPDATES HAND ASSEMBLY ARRAY LOC.
1400 SN=P:TP(6)=TP(6)+50
1425 REM 'LEFT' FOR HAND ASSEMBLY, VALID ONLY IN MODE 2, UPDATE ARRAY
1450 FOR I=0 TO 7: POKE SB+I,P: POKE HB+I,0: POKE LB+I,0: NEXT I: POKE SB+6,SN: POKE LB+6,80: CALL -28672: GOTO 190
1500 SN=M:TM(6)=TM(6)-50: GOTO 1450
1525 REM 'RIGHT' FOR HAND ASSEMBLY, VALID ONLY IN MODE 2, UPDATE ARRAY
2000 VTAB (10): FOR I=0 TO 8:T(I)=TM(I)+TP(I):TM(I)=0:TP(I)=0: NEXT I
2005 REM 'ENTER' COMMAND: ADD +/- TM AND TP ARRAY ELTS
2010 FOR I=0 TO 7: POKE SF+I,P: IF SGN (T(I))=-1 THEN POKE SF+I,M
2012 REM UPDATE GLOBAL SIGN BUFFER
2015 X= ABS (T(I)):Y=X MOD 100:X=X/100:
2020 POKE HF+I,((X/10)*16)+(X MOD 10): POKE LF+I,((Y/10)*16)+(Y MOD 10): NEXT I:SF=SF+8:LF=LF+8:HF=HF+8
2025 REM CONVERT MOVES TO BCD AND STORE IN HI AND LO GLOBAL BUFFERS
2030 CT=CT+1: POKE CNT,CT: GOTO 190
3000 VTAB 7: TAB 1: PRINT "YOUR COMMAND ";
3005 REM COMMAND ENTRY ROUTINE
3010 IN#SLOT: INPUT A: IN#0: PR#0: TAB 1
3020 VTAB 5: PRINT "YOU SAID ";I$(A*6-5,A*6);" ?": RETURN
4000 PRINT "": GOSUB 3000: IF A<11 THEN 4000
4005 REM 'CHANGE' COMMAND ALL KINEMATICS INVALID HERE, GET MORE INPUT
4010 IF A=11 THEN MD=1 : REM SET 'ALL' MODE
4020 IF A=12 THEN MD=2 : SET 'HAND' MODE
4030 IF A=13 THEN 5000 : REM GOTO 'RUN' ROUTINE
4032 IF A=14 THEN IF CT<93 THEN 2000: REM IF LESS THAN 93 MOVES THE DO 'ENTER'
4035 A=0 : REM SET COMMAND RETURNED VAL TO 0
4040 GOTO 190
5000 VTAB 20: TAB 1: PRINT "RUN ";: INPUT Q$: IF Q$="" THEN 190: IF Q$(1,1)="#Y" THEN 190
5004 REM VERIFY 'RUN' COMMAND WITH KEYBOARD CONFIRMATION IF 'N' GET NEW COMMAND
5005 POKE -16384+16,0: POKE -16384,0
5010 FOR I=BU TO (SF-8) STEP 8: REM FROM BEGIN OF GLOBAL TO END
5020 FOR J=0 TO 7:X= PEEK (I+J): IF X= ASC("**")-128 THEN 6000
5021 REM IF '*' IN GLOBAL THE DO 'HOME' ROUTINE
5025 POKE SB+J,X
5026 REM TAKE SIGN FROM GLOBAL AND PUT INTO 'ALLMOS' MOTOR DRIVER
5030 X= PEEK (I+768+J): POKE HB+J,X
5031 REM TAKE HI MOTOR BYTE FROM GLOBAL AND PUT INTO 'ALLMOS' MOTOR DRIVER
5035 X= PEEK (I+768*2+J): POKE LB+J,X
5036 REM TAKE LO MOTOR BYTE FROM GLOBAL AND PUT INTO 'ALLMOS' MOTOR DRIVER
5040 NEXT J: CALL -28672:
5041 REM ONE MOVE TRANSFERRED, CALL DRIVER
5045 NEXT I : REM DO FOR ALL MOVES IN GLOBAL
5050 A= PEEK (-16384): IF A<128 THEN 5010
5055 REM IF KEYPRESS THEN EXIT ELSE DO ALL MOVES AGAIN
5060 MD=1: POKE -16384+16,0: POKE -16384,0: GOTO 190
6000 CALL -28160 : REM CALL 'HOME' ROUTINE
6010 GOTO 5045 : REM RETURN FOR NEXT MOVE IN GLOBAL
6050 END

```

Listing 1. The control program ROBOVOX. This program, written in Apple Integer BASIC, provides the means for obtaining and evaluating the spoken commands returned by the Heuristics Speechplot card. It uses two assembly-language routines, which control the Rhino XR-1 robot.

ignored and another is requested. The chances of a recognition error occurring in the options within any mode is smaller than the possibility of error between mode subsets, thus enhancing overall reliability. Table 1 contains a summary of the language's commands.

Program Analysis. The control program (listing 1), written in Integer BASIC, uses two assembly-language routines to actually drive the robot. Each command moves the joint motors corresponding to that command 50 encoder steps. Each ENTER command updates the global move buffer (an

area of the Apple's memory where the recorded moves are stored) with the total number of steps executed by the active motors since the previous ENTER command. The RUN command executes all the moves stored in the global buffer by repeatedly calling the ALLMOS assembly-language driver and performing all moves in turn until the buffer is empty. The stored move sequence is executed continuously or until any key is pressed.

The BASIC program, called ROBOVOX, requires that the operator train the system by reciting each command word twice. Two independent samples of each command are

thus available for matching against future input. The resulting digitized spectral sample is then stored. The training session occurs in lines 40-100.

The subroutine at line 3000 obtains the input command and displays the recognized command on the screen. The program stops if the operator types X at any time during command entry. If the speech card cannot recognize the word, it returns a value greater than the number of commands (14) and requests another command.

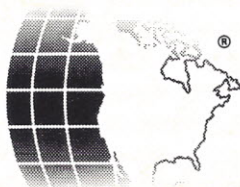
The commands are decoded in lines 200-270. A returned value of 10, corresponding to the CHANGE command,

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results in a jump to line 4000, where further input is requested. If, at this point, the card returns a value of less than 11 (a value which would correspond to a move within one of the two coordinate frames), the command is invalid and the program requests another command. A returned value of 11 sets the current coordinate frame to ALL in line 4010. If the request is the RUN command (a value of 13), execution jumps to line 5000, where keyboard confirmation is obtained. If the ENTER command is specified, and, if there are fewer than 93 moves in the global move buffer, execution jumps to line 2000, where the current move is added to the global input buffer.

If the speech card returns a value between 1 and 8, the motion commands are executed. The first six commands are valid in the base-shoulder-elbow coordinate frame (the ALL frame). When the system is in the HAND mode, lines 230-260 test for valid input, while lines 280-285 transfer control to the routines that move the hand assembly. Lines 300-1500 set up the assembly-language driver with the number of steps each active joint is to be driven, followed by a call to the driver, which is located at address hexadecimal 9000 (decimal -28672).

Conclusion. The simple strategy of partitioning the command set into modes, where only four commands are valid, makes a relatively uncomplicated program quite effective and helps to offset the inherently low reliability of the simple voice recognition card used. The program was tested in demonstrations with naive users with enough success to warrant investigation of this approach using more sophisticated input devices. □

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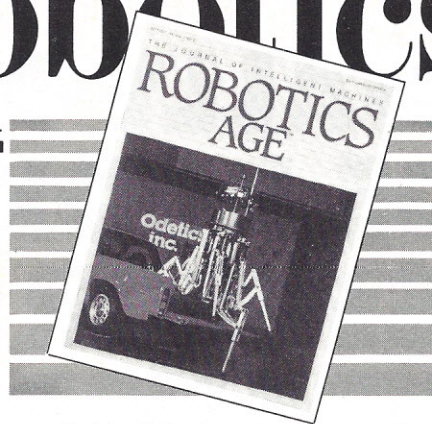
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Part II

Scorpion

Motor Control Instructions

Harprit S. Sandhu
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Last month, I presented an overview of the Scorpion design parameters and language commands. The following article describes the basic motor control instructions in detail.

The 8K byte EPROM provided with each Scorpion contains the complete Scorpion operating system. The software only uses approximately 4K bytes of the available EPROM leaving room for expansion. This operating system provides instructions for controlling all aspects of the Scorpion hardware.

Drive Motors. Drive motor control is designed to reduce the overhead on the host computer. The speed to be maintained by each motor and the motor direction are transmitted to the Scorpion to start the two drive motors. The controlling computer does not have to control the individual steps. Once the movement command has been issued, it will continue to move until another motor speed command is issued, a microswitch on one of the motors is activated, the reset button is pressed, or the system reset command is sent to the on-board computer.

Speed Control. Motor speed is controlled by a movement pulse which is sent to each motor at a designated frequency. The frequency is determined by a countdown timer. The Scorpion uses one timer on each of the 6522s to control a motor. Motor direction is changed by altering the count in each timer.

Each timer contains a 16-bit register that can contain a number from 0 to 65535. This number is decremented at the clock rate. Since the Scorpion's system clock

operates at 920 kHz, the maximum value of 65535 would cause the counter to reach zero 14 times per second. Since this is too fast for the motors, we use a control subroutine to step the motors once for every 14 times the counter reaches zero. Every time the motor is actually stepped, the subroutine updates the motor movement counter.

Motor speed is changed by altering the count in the 6522 counter. The lower the count, the higher the motor speed. There is a limit to how fast you can toggle the stepper motor. The stepper motors we use should not be stepped more than 200 times per second. This would produce approximately 250 revolutions per minute (4.17 revolutions per second) at the drive motors and 42 revolutions per minute at the wheel after the 6-to-1 reduction. These numbers translate into a 49 feet per minute maximum speed.

The motor control instruction is nine bytes long. A typical instruction, such as "/7M+23+35," is interpreted as follows:

- "/" indicates the following information is an instruction.
- "7" indicates 7 data bytes to follow.
- "M" indicates a motor move.
- "+" indicates the motor direction for the left motor.
- "23" indicates the speed for the left motor.
- "+" indicates the direction for the right motor.
- "35" indicates the speed for the right motor.

Each motor has 99 speeds in each direction. The computer converts the speed requested to the proper count for the timers.

Speed 00 is valid; it turns off the motor.

One step on a drive motor moves the Scorpion 0.0491 inches. A five-byte movement counter allows the computer to track a distance of up to ± 9999 moves. This is equivalent to 40 feet.

Optical Scanner. The three instructions for controlling the optical scanner are Reset, Move, and Scan. Individual instructions exist for the horizontal and vertical axes.

Before we can move the optical scanner intelligently, we must know our starting position. The Reset instruction returns the optical scanner to a known "home" position. The two Reset operations (/2HR and /2VR) are used to reset the horizontal and vertical axis.

The Reset instruction starts the scanner moving towards a "home" position. The scanner moves 240 steps in the counter-clockwise direction. Since each axis of the optical scanner has a stop, and there are only 240 steps per axis, this procedure guarantees that the scanner stalls against the stop. Once the scanner is positioned against the stop, the Reset instruction moves the scanner back 120 steps. This places the optical scanner in a forward-looking position.

The Move instruction produces motion relative to the current motor position. A command such as "/5HM-03" instructs the horizontal motor to move 3 steps in the counter-clockwise direction. "/5HM+03" would move the motor three steps in the clockwise direction. Corresponding commands are available for controlling the vertical axis, simply substitute "V" for "H" in the commands.

The Scan instruction moves the optical scanner through a defined number of horizontal or vertical steps. A typical instruction, "/4HS15" is interpreted as follows:

- "/4" indicates a four-byte command.
- "H" indicates the horizontal scanner.
- "S" indicates a scan request.
- "15" the last two digits define the scan extent.

The scan extent value is interpreted as the number of steps to either side of the current scanner position through which the scanner moves. A value of 15 indicates that the scanner should move 15 steps counterclockwise and read a brightness value. The scanner then steps clockwise reading a brightness value at each step. The scanner continues to collect brightness information for $15 \times 2 + 1$ steps. Note that a scan of 1 produces three

brightness values. A scan of zero produces a single brightness value.

Vertical scans are performed in a similar manner to horizontal scans. The vertical Scan instruction substitutes the letter "V" for "H."

Additional Controls. The Scorpion system also has the ability to turn two LED "eyes" on and off, generate sounds through an onboard speaker, and track a path on the ground.

The eye control instruction has only four variations. "/2E0" turns both eyes off, "/2E1" turns on the right eye, "/2E2" turns on the left eye, and "/2E3" turns on both eyes.

The onboard speaker is controlled through two parameters, frequency and duration. The command model is "/5Sffdd."

- "/5S" indicates a five-byte speaker

command.

- "ff" = a two-byte frequency value. 00 indicates no tone. Frequencies from 1 to 48 provide four octaves from 117 cps to 1760 cps (A# below low C to A above high C). Frequencies from 60 to 99 are defined by the user.

- "dd" = a two-byte duration value. Durations vary from 0 to 2.5 seconds for values from 00 to 99. ☐

Next month. The concluding section of this article describes the second half of the instruction set and describes how the Scorpion control language can be extended with custom instructions.

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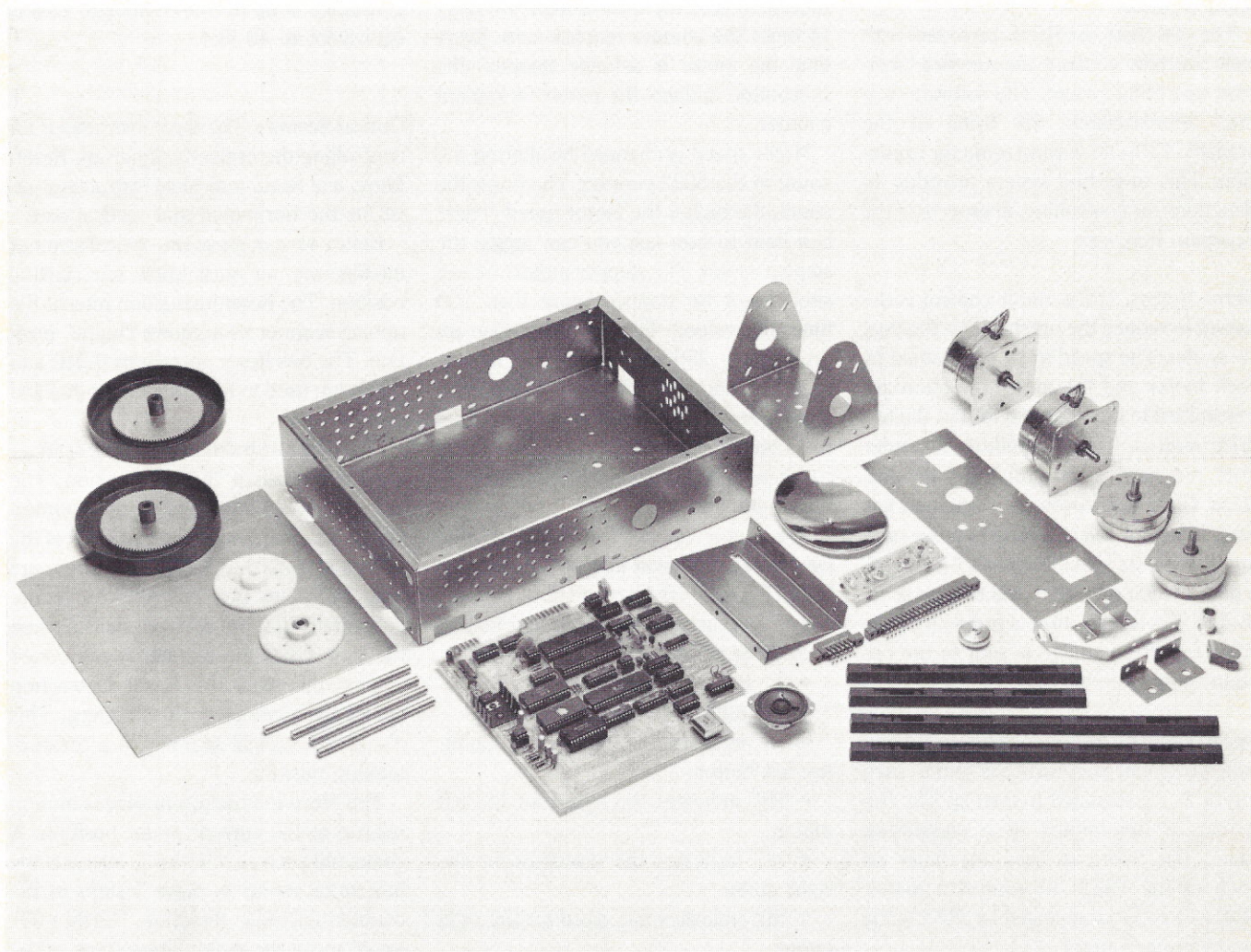


Photo 1. MAJOR COMPONENTS. Included among the major components of the Scorpion are the main drive wheels, cover plate, gears, axles, chassis, controller card, speaker, scanner reflector, bumpers, and other parts. Various small items such as screws, nuts and bolts, and microswitches, are not shown here but are also included in the kit.

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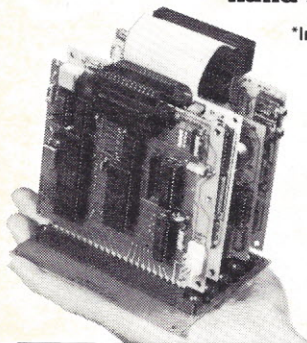
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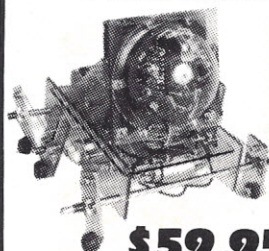
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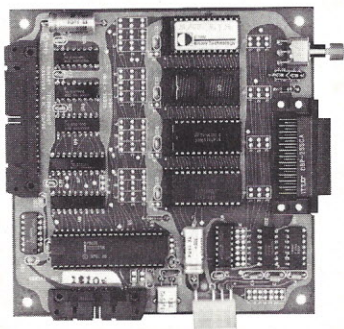
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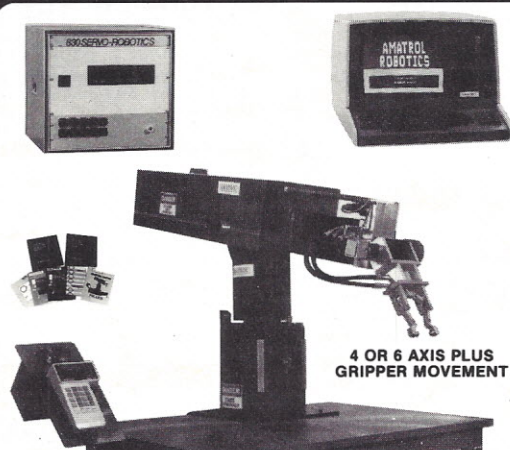
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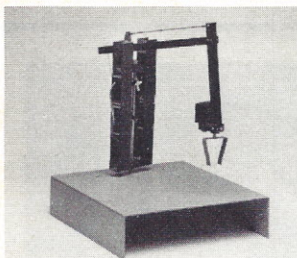
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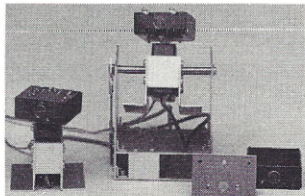
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VISION 2D KIT \$135

Adds tilt for TV image. Full grey scale. Easy to use with BASIC. Pattern recognition, X-Y tracking, Robot Vision.



VISION 0 KIT \$40; 2 for \$70

Fixed view and proximity detect.

Interface kits for several computers, more arms and vision units.

WRITE OR CALL FOR CATALOG.

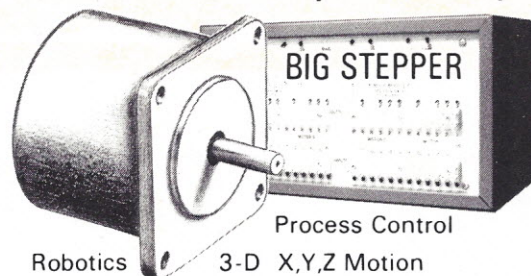


SPECTRON INSTRUMENT

1342 W. Cedar Ave. Denver, CO 80223
Telephone (303) 744-7088



Stepping-Motor Driver Box with on board BASIC in ROM Controls Motion from any CRT or Computer



Robotics

3-D X,Y,Z Motion

HOOKUP AND GO! Provides all required power

Drives 4 motors at up to 5 amps per winding
while sensing 8 limit switches

STEPPING-MOTOR TIPS COOKBOOK: \$8

with 3-D software & schematic

BIG STEPPER:

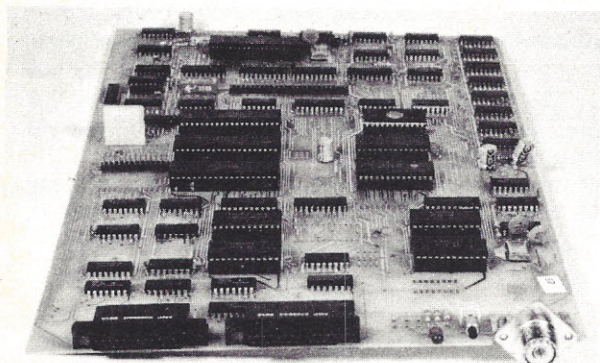
Parallel Version \$495/card only \$195

Smart Version (RS232) \$850/with BASIC \$985

Centre Computer Consultants, (814) 237-4535

P.O. Box 739, State College, PA 16804

MC-2 HARDWARE / MTS SOFTWARE



MC-2 base board \$279.00

Z-80 CPU at 4 MHz, 64K RAM, CTC, PIO, expansion bus, requires +5V/1A. MTS/Monitor/drivers in ROM.

On board options

CRT 64 64 character x 16 line video generator \$109.00

CRT 80 80 character x 24 line video generator \$149.00

SIO RS-232 Two serial channels \$ 59.00

POWER SUPPLY 5V2A, +12/-12V, .4A \$ 59.00

MTS-Z80 OPERATING SYSTEM source code \$ 99.00

MTS-Z80 manual \$ 12.00

MTS-BASIC Reentrant control Basic \$ 79.00

Z80 CP/M* MACRO ASSEMBLER \$ 49.50

*CP/M is a trademark of Digital Research.



CYBERPAK

PO Box 38, Brookfield IL 60513
(312) 387-0802



ELECTRONICALLY SPEAKING

Electronically Speaking: Computer Speech Generation is the newest introduction to electronic speech to be published by Howard W. Sams & Co., Inc.

Author John Cater presents the basic background knowledge necessary to understand synthesized speech along with an historical account of early speech synthesizers, both mechanical and electrical. The author covers the speech synthesis methods in common use today: waveform encoding/decoding; analog formant frequency speech synthesis; analog formant speech frequency synthesis; and linear predictive coded (LPC) speech.

A chapter describing off-the-shelf speech synthesis systems provides overviews and system diagrams of products such as the TI Speak-and-Spell™, Votrax TypeN Talk™, and Kurzweil Reading Machine.

The book closes with a collection of speech synthesis application circuits ranging from a simple dynamic microphone amplifier to voice sampling and reconstruction circuits.

Price: \$14.95. Our Price: \$13.00 shipping included. Overseas Surface Add \$2.00. Overseas Air Mail Add \$6.00

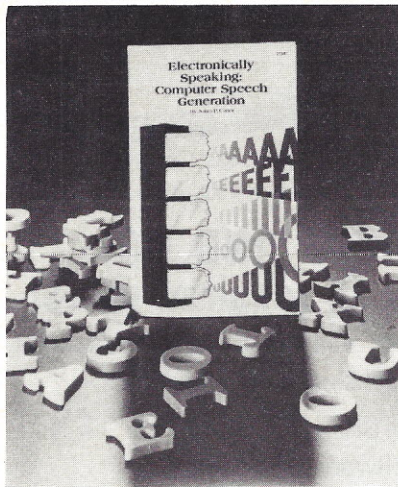
Check, Money Order, MasterCard, and VISA accepted. Checks must be drawn in US funds. MC and VISA customers must include card number, interbank number, and card's date of expiration.

Peterborough Distribution Services

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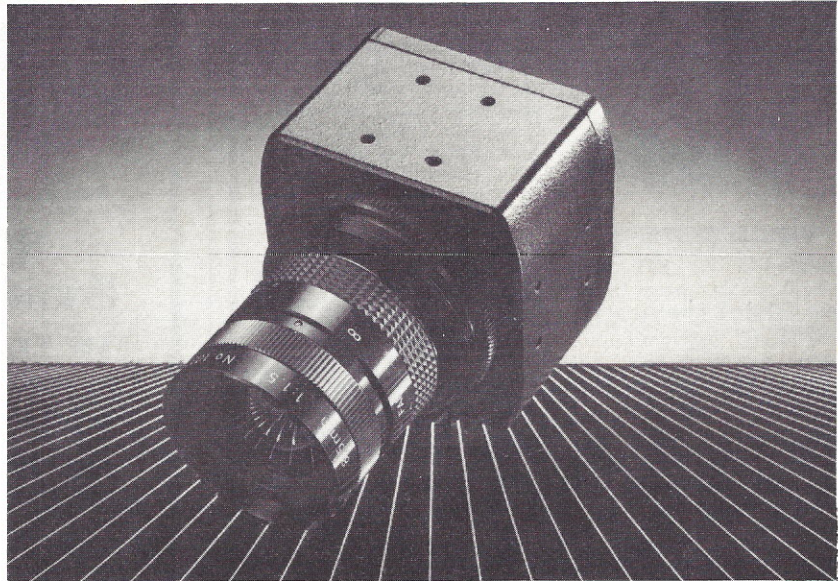
Peterborough, NH 03458

New Products



Speech Information

Two new books from Howard W. Sams & Co., Inc. discuss the theory and practice of synthetic speech. *Introduction to Electronic Speech Synthesis* by Neil Sclater, written in nontechnical language, is an investigation into how human-sounding speech is recreated synthetically using new electronic methods. This 134-page text, available for \$8.95, is the latest addition to Sams's Blacksburg Continuing Education Series.TM *Electronically Speaking: Computer Speech Generation* by John P. Carter is a practical guide to current technology and circuitry, with hardware and software presented that permits synthetic speech generation on popular microcomputer systems. This 230-page volume is available now for \$14.95. Circle 31



Lightweight Solid State Camera

EG&G Reticon's Model MC9128 solid state camera weighs less than 12 ounces and is designed for image sensing applications in robotics and other automation environments. All conventional "C," "U," and Nikon Bayonet lenses will adapt to the MC9128.

The camera incorporates a 128 by 128 pixel solid state image sensor mounted directly onto a thick-film hybrid microcircuit which contains all drive and timing electronics. The MC9128 requires only a single-phase clock and DC power to operate at video rates exceeding 8 MHz.

Balanced differential analog and digital I/O drivers permit the camera head to be connected up to 12 feet away from the host processor. Special features include an automatic frame reset (electronic shutter) which simultaneously discharges all pixels, and "Y" clock mode which permits the user to skip any number of rows in a frame. The Model MC-9128-2 is priced at \$1,500 in unit quantities.

For more information, contact: EG&G Reticon, 345 Potrero Ave., Sunnyvale, CA 94086-9930, telephone (408) 738-4266.

Circle 32

Engineering Model Simulator for IBM PC

Appled i has released the IBM PCTM version of TUTSIM,TM a simulation program originally developed for minicomputers.

The interactive TUTSIM (Twente University of Technology Simulator) program is an engineering design tool and teaching aid that models such complex continuous systems as electronic circuits, chemical reactions, economic models, and the human heartbeat. Results are displayed graphically or numerically.

TUTSIM, which is also available for the

Apple IITM, CP/MTM, and PDP-11TM, allows you to solve problems by constructing and operating a block diagram simulation of the system, and evaluating the graphic or numerical result.

Allowing the use of up to 999 blocks per model, TUTSIM enables graphic representation of linear or nonlinear system behavior using more than 40 analog, logic, and dynamic functions, including PID-regulator, sample and hold, a user-defined function generator, and floating-point arithmetic. Model design can be varied, blocks may be

added or deleted, interconnections can be changed, and parameters and values can be altered at any time during the simulation.

TUTSIM for the IBM PC supports the IBM color graphics adapter board and requires only 64K bytes of memory. Single quantity price is \$425. A demonstration diskette and manual are available for \$18.75.

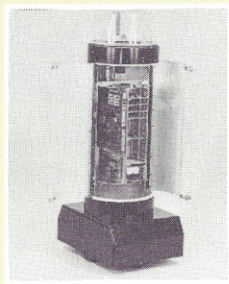
For more information, contact: Applied i, 200 California Avenue, Suite 205, Palo Alto, CA 94306, telephone (415) 325-4800.

Circle 33

1984 ROBOTICS AGE PRODUCT GUIDE

Robotics Age Product Guide:

A Sourcebook for
Educators & Experimentalists



Sentry Robots. Aids for the Disabled. Voice Control. Artificial Intelligence. These are the buzz words of the eighties. The words of an exciting, new world.

To learn about robotics, you must do more than read, you must experiment.

Where can you find in-depth information about affordable robotic equipment?

Though several industrial robot directories already exist, no directory has yet been published which describes the inexpensive equipment available for use with personal and modular, board-level computers. Until now.

The Sourcebook

The *1984 Robotics Age Product Guide: A Sourcebook for Educators and Experimenters*, is packed with hundreds of descriptions containing vital information about inexpensive robotics products. The Robotics Age Product Guide is essential reading and research material for all educators, research and development engineers, and experimenters.

Product Guide listings run the full gamut of robotics products: self-contained robots and robotic arms, turtles, vision systems,

speech generation and recognition products, robot control languages, personal robot peripherals and ultrasonic ranging systems. No other publication can bring you the same in-depth information.

The Product Guide delivers useful descriptions, names of

contact people, and product photographs.

Intelligent machines are part of our daily lives. Stay in the forefront of this new technology. Read the *1984 Robotics Age Product Guide: A Sourcebook for Educators and Experimenters*.

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New Products



14-Axes Motion Control

The C-1012 Programmable Motion System from Buckminster Corporation offers precise, yet easy-to-use digital control of up to 14 axes. The C-1012 is a complete system which includes servomotors, amplifiers, microprocessors, and all power supplies.

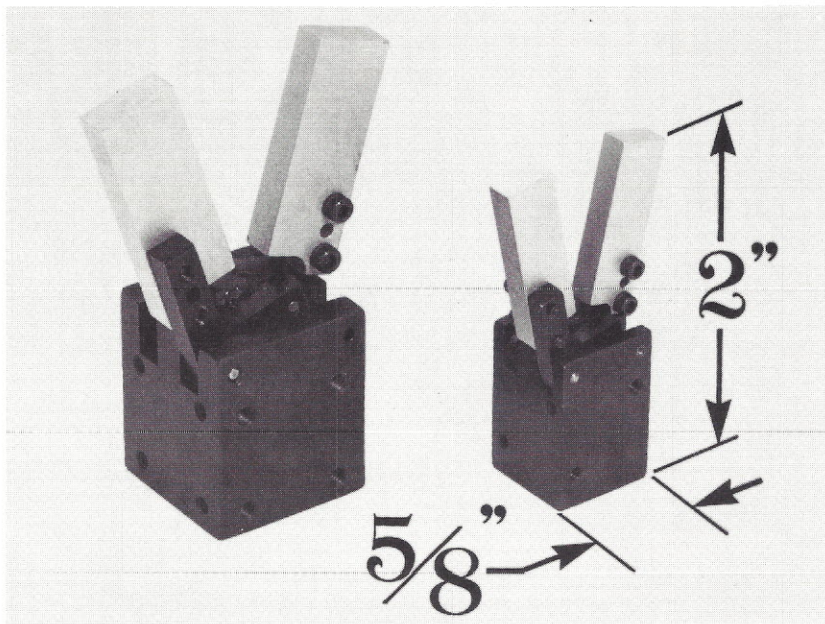
The C-1012 is programmable in either BASIC or assembly language. System software includes a menu-driven utility library, text editor, and EPROM programmer. It requires 120 VAC and can be programmed from any terminal via an RS-232 connection.

The C-1012 Programmable Motion System is useful for many kinds of position and motion control, from single-axis point-to-point positioning to complex coordinated motion (trajectory control) among several axes. Typical applications include performance testing, XY table control, and dimensional inspection of critical components. In robotics applications, the C-1012 can be used for compliant motion, synchronized slave drives, and precision assembly.

Speed range is up to 10,000 RPM; acceleration up to 500,000 radians/s.² Positioning is accurate to 0.01°. Analog tachometers provide velocity feedback, which in turn enhances position loop stability and other dynamic characteristics. Optical incremental encoders close the feedback loop for high-resolution positioning.

Included with every C-1012 system is a 300-page technical manual containing complete instructions for BASIC programming, system installation and operation, as well as schematics and detailed product information on all subsystem components. In addition, Buckminster provides free hands-on training for each C-1012 purchased.

For more information, contact: Maggie Erskine, Buckminster Corporation, 99 Highland Avenue, Somerville, MA 01243, telephone (617) 864-2456. Circle 34



Standard Miniature Grippers

A standard line of miniature grippers is now available from PHD, Inc. These pneumatically-operated grippers are available in three sizes and can be used for both internal and external gripping with forces up to 10 lbs.

These compact lightweight grippers are

ideal for small part pickup and can be used on special machines as end effectors on industrial robots, or with various other PHD modular automation components.

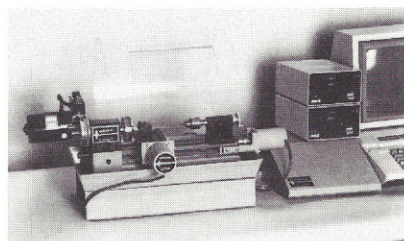
For more information, contact: PHD, Inc., P.O. Box 9070, Fort Wayne, IN 46899, telephone (219) 747-6151. Circle 35

Light Machine Lathe

A computer-controlled lathe developed by Light Machines Corporation operates as a peripheral for the Apple IIe,TM IBM PCTM and DEC RainbowTM personal computers. Using conventional CNC code, the Watchmaker CNC system duplicates most of the operations of full-sized CNC lathes.

With resolution of ± 0.0001 inch within its 3-inch diameter by 8-inch-long cutting volume, Watchmaker CNC is intended for small machine shops, high-precision turning, and especially for educating new operators in CNC technology at low machine risk.

The BASIC-compatible software harnesses the power of the personal computer to emulate the complete standalone CNC controllers. The user may add special functions



to fit his needs: polynomial-fit curve cutting, joystick control of tool movement, tool-force sensing, or many other possibilities.

The basic Watchmaker CNC system sells for less than \$2500, excluding the cost of the controlling computer.

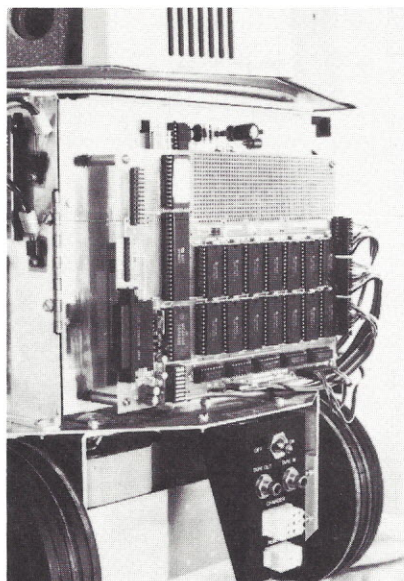
For more information, contact: Oliver J. Edwards, Marketing Manager, Light Machines Corporation, 649 East Industrial Drive, Manchester, NH 03103, telephone (603) 625-8600. Circle 36

New Products

Hero 1 Add-Ons

Micromation, Inc. markets a variety of peripherals for the Heathkit Hero 1 robot. The company's MEMCOM board (see photo) provides a means to develop programs for the robot using a personal computer. The board expands the available programmable memory to 30K bytes. A wire-wrapping area is provided to allow expansion and experimentation. The board connects directly to the Hero processor board's address, data, and control buses.

The MEMCOM board includes a 6522 VIA chip which provides two 16-bit timers and two 8-bit bidirectional parallel ports with handshaking lines for fast data transfers between the robot and a computer (can be connected directly with Micromation, Inc.'s Apple-Hero Communicator Board). An RS-232 serial port for two-way communications is implemented using a 6850 ACIA chip. Serial communications software in an onboard EPROM allows you to upload and



download programs. 14 of the 2K byte programmable memory chips are socketed to allow substitution of EPROM chips. All hardware necessary to mount the MEMCOM board on the rear door of the Hero 1 is provided.

The MEMCOM board uses memory locations hexadecimal 4000 through B7FF. Locations hexadecimal B800 through BFFF are used for I/O purposes, and B000 through B7FF is occupied by an EPROM which may be replaced by programmable memory. The MEMCOM board is priced at \$295.

Other Micromation, Inc. products include VOCOL, the Voice Command Language, and VOREC, a speech recognition board.

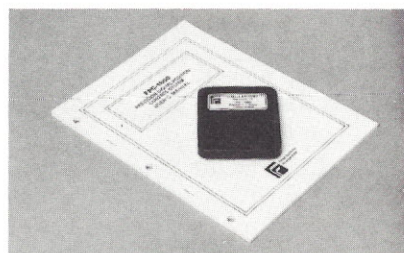
For further information, contact: Micromation, Inc., 9104 Red Branch Road, Columbia, MD 21045, telephone (301) 730-1237.

Circle 37

Digital Servo Controller

The FPC-1800 from Finell Systems is a modular, programmable digital servo controller designed for closed-loop servo positioning applications. Contained within the FPC-1800 is a high-speed microcomputer which computes a control algorithm in real time. The algorithm uses user-programmed parameters to define characteristics of the servo loop. Variations in loop characteristics can be compensated for by optimizing loop-parameter constants.

A user manual is available to demonstrate techniques for calculating parameter inputs. Simple handshake interface to a host computer is accomplished with a bidirectional



8-bit parallel port. A 12-bit digital-to-analog converter converts digital data to an analog output signal. When used with a shaft encoder, DC amplifier, or pulse width modulator and a bridge amplifier, the result is an intelligent, high-performance, DC motor positioning system.

In addition to microprocessor control, the unit features user-programmable servo loop parameters, velocity load control, guaranteed stability, adaptability, and a compact size. Applications include most equipment found in industrial usage, from machine tools, numeric control and manufacturing process equipment, to semiconductor process and production, robotics, CAD/CAM, material handling, and medical scanning equipment.

For more information contact: Finell Systems, Inc., 1190-S Mountain View-Alviso Road, Sunnyvale, CA 94086, telephone (408) 734-9783.

Circle 38

Text to Speech Conversion Software

Ackerman Digital Systems' SPK program can convert English language text to a string representing the International Phonetic Alphabet (IPA) pronunciation using the rules and algorithms published by a team at the Naval Research Laboratory (Report NRL #7948 by Elovitz, Johnson, McHugh, and Shore, 1976). SPK uses the entire 318 rule set defined in the NRL report. Further, the option of using an

external rule set allows you to define your own rule set, or to refine the NRL rules.

According to the authors of Report NRL #7948, "Using the 50,000-word Standard Corpus of Present-Day Edited American English ('Brown Corpus'), we have determined that the rules produce correct pronunciations for approximately 90 percent of the words in an average sample of English text."

Written in C, SPK can be transferred to any operating system with a C compiler that behaves like the standard Berkeley Unix C compiler. The current implementation was compiled using Aztec C running under the CP/M operating system.

For more information, contact: Ms. Lawrie N. Ackerman, Ackerman Digital Systems, Inc., 110 North York Road, Suite 208, Elmhurst, IL 60126, telephone (312) 530-8992.

Circle 39

Basic Robotic Automated Trainer

401 N. Salem Avenue
Arlington Heights, IL 60005
(312) 870-0883

Circle 2



By **AMPTRONICS**

THIS IS ONE "BRAT" YOU'LL WANT IN YOUR CLASSROOM!



- **Multiple Technologies** — capable of instructing students in electricity/electronics, pneumatics, mechanics and programming.
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Systems designed to survive real world training